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IDA RECORD DOCUMENT D-24

AN/TPQ-36 AND AN/TPQ-37 FIREFINDER RADARS CASE STUDY REPORT

(IDA/OSD R&M STUDY)

AD-A142 104

Paul F. Goree
IDA R&M Case Study Director

August 1983

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(Manpower, Reserve Affairs and Logistics)

IDA

INSTITUTE FOR DEFENSE ANALYSES

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document records the activities and presents the findings of the AN/TPQ-36 and AN/TPQ-37 Firefinder Radar Case Study Working Group part of the IDA/OSD Reliability and Maintainability Study, conducted during the period from July 1982 through August 1983.

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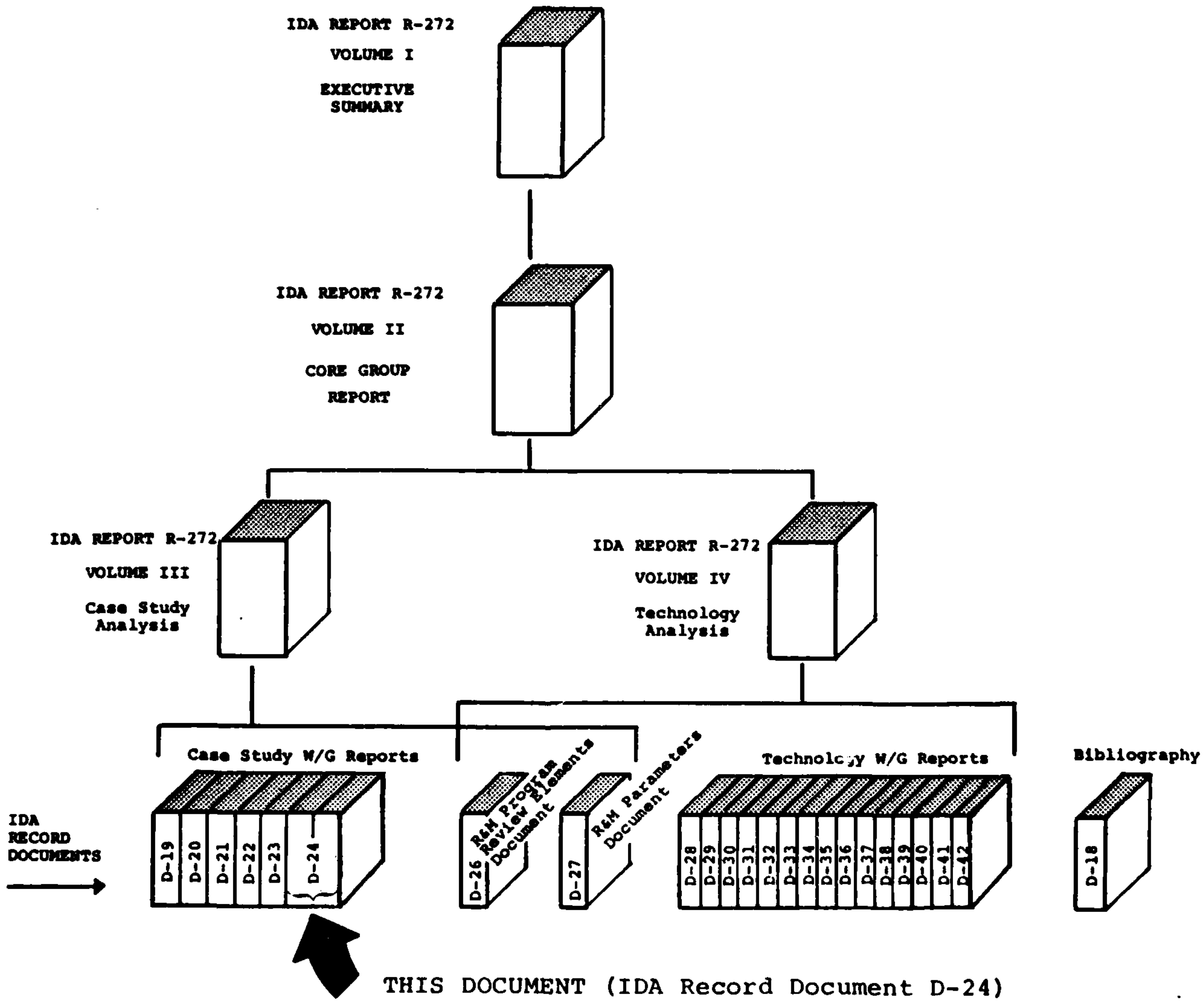
INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311
Contract MDA 903 79 C 0018
Task T-2-126

RELIABILITY AND MAINTAINABILITY STUDY

— REPORT STRUCTURE —



PREFACE

As a result of the 1981 Defense Science Board Summer Study on Operational Readiness, Task Order T-2-126 was generated to look at potential steps toward improving the Material Readiness Posture of DoD (Short Title: R&M Study). This task order was structured to address the improvement of R&M and readiness through innovative program structuring and applications of new and advancing technology. Volume I summarizes the total study activity. Volume II integrates analysis relative to Volume III, program structuring aspects, and Volume IV, new and advancing technology aspects.

The objective of this study as defined by the task order is:

"Identify and provide support for high payoff actions which the DoD can take to improve the military system design, development and support process so as to provide quantum improvement in R&M and readiness through innovative uses of advancing technology and program structure."

The scope of this study as defined by the task order is:

To (1) identify high-payoff areas where the DoD could improve current system design, development program structure and system support policies, with the objective of enhancing peacetime availability of major weapons systems and the potential to make a rapid transition to high wartime activity rates, to sustain such rates and to do so with the most economical use of scarce resources possible, (2) assess the impact of advancing technology on the recommended approaches and guidelines, and (3) evaluate the potential and recommend strategies that might result in quantum increases in R&M or readiness through innovative uses of *advancing technology*.

The approach taken for the study was focused on producing meaningful <u>implementable</u> recommendations substantiated by quantitative data with implementation plans and vehicles to be provided where practical. To accomplish this, emphasis was placed upon the elucidation and integration of the expert knowledge and experience of engineers, developers, managers, testers and users involved with the complete acquisition cycle of weapons systems programs as well as upon supporting analysis. A search was conducted through major industrial companies, a director was selected and the following general plan was adopted.

<u>General Study Plan</u>

Vol. III ● Select, analyze and review existing successful program

Vol. IV ● Analyze and review related new and advanced technology

Vol. II (● Analyze and integrate review results
(● Develop, coordinate and refine new concepts

Vol. I ● Present new concepts to DoD with implementation plan and recommendations for application.

The approach to implementing the plan was based on an executive council core group for organization, analysis, integration and continuity; making extensive use of working groups, heavy military and industry involvement and participation, and coordination and refinement through joint industry/service analysis and review. Overall study organization is shown in Fig. P-1.

The basic case study approach was to build a foundation for analysis and to analyze the front-end process of program structuring for ways to attain R&M, mature it, and improve it. Concurrency and resource implications were considered. Tools to be used to accomplish this were existing case study reports, new case studies

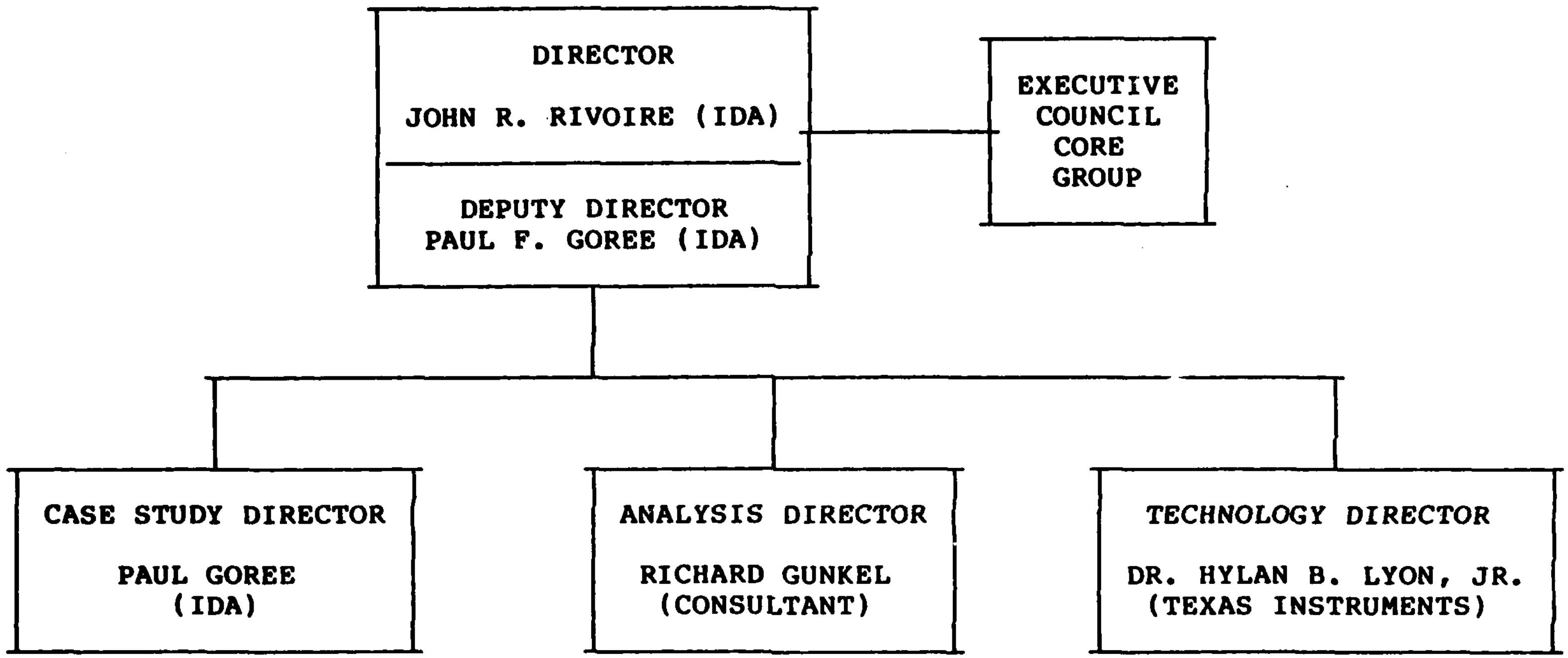


FIGURE P-1. Study Organization

conducted specifically to document quantitative data for cross-program analysis, and documents, presentations, and other available literature. In addition, focused studies for specific technology implications were conducted by individual technology working groups and documented in their respective reports. To accomplish the new case studies, the organization shown in Fig. P-2 was established.

In some areas where program documentation and records did not exist, the actual experience and judgement of those involved in the programs were captured in the case studies. Likewise, in the analysis process, the broad base of experience and judgement of the military/industry executive council members and other participants was vital to understanding and analyzing areas where specific detailed data were lacking.

This document records the program activities, details and findings of the Case Study Working Group for the specific program as indicated in Fig. P-2.

Without the detailed efforts, energies, patience and candidness of those intimately involved in the programs studied, this case study effort would not have been possible within the time and resources available.

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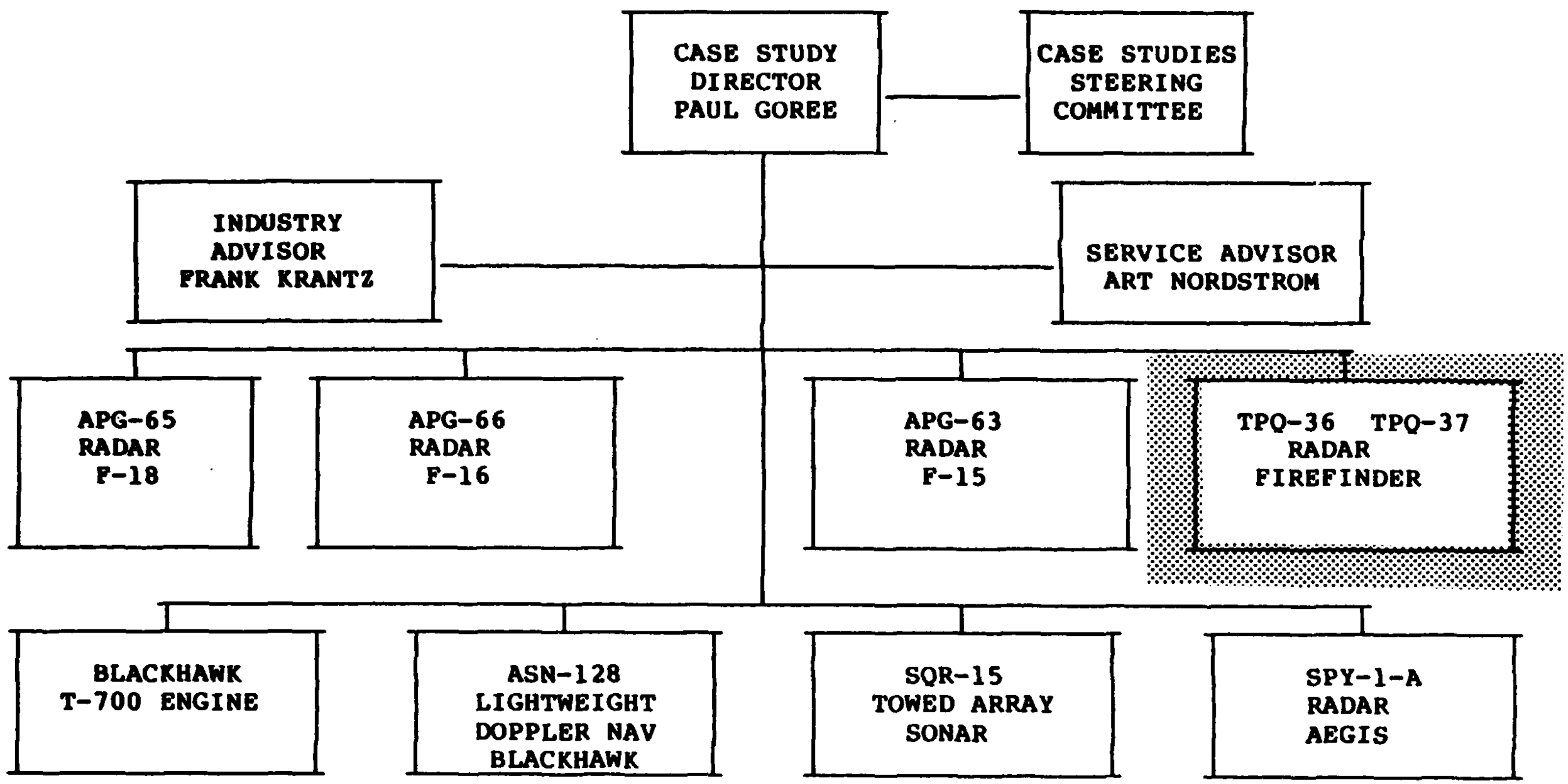

FIGURE P-2. Case Study Organization

AN/TPQ-36 AND AN/TPQ-37 FIREFINDER RADARS

RELIABILITY AND MAINTAINABILITY

CASE STUDY

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R&M PROGRAM REVIEW ELEMENTS

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4. R&M Failure Definition
5. Incentives
6. Source Selection Criteria
7. LCC Consideration

MANAGEMENT

8. Planning Control & Emphasis
9. Monitor/Control of Subcontractors & Suppliers

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ABBREVIATIONS

A/T	Antenna-Transceiver
ATE	Automatic Test Equipment
ASARC	Army System Acquisition Review Council
BIT	Built-in-Test
BSU	Beam Steering Unit
CCA	Circuit Card Assembly
CDR	Critical Design Review
CFE	Contractor Furnished Equipment
DARCOM	Army Material Development and Readiness Command
DESC	Defense Electronics Supply Center
DS	Direct Support
DT	Development Test
DTC	Design to Cost
DTUPC	Design to Unit Production Cost
ED	Engineering Development
EDM	Engineering Development Model
EMI	Electromagnetic Interference
ETI	Elapsed Time Indicator
EPR	Equipment Performance Report
ERADCOM	Electronic Research and Development Command
ESS	Environmental Stress Screening
FFP	Firm Fixed Price
FIAR	Failed Item Analysis Report
FRACAS	Failure Reporting Analysis and Correction
FRB	Failure Review Board
GS	General Support
HAC	Hughes Aircraft Company
HVPS	High Voltage Power Supply
HWLS	Hostile Weapon Locating System
IC	Integrated Circuit
ILS	Integrated Logistic Support (System)
LED	Light Emitting Diode
LRIP	Low Rate Initial Production
LRU	Line Replaceable Unit
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
OMR	Operation and Maintenance Report
OT	Operational Test
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
PFRB	Project Failure Review Board
PRT	Preliminary Review Team
RAM	Reliability Availability and Maintainability
R&M	Reliability and Maintainability
RAT	Reliability Acceptance Test
REA	Responsible Assigned Engineer
RF	Radio Frequency
RFP	Request for Proposal
SCR	Silicon Control Rectifier
TAAF	Test, Analyze and Fix
TDA	
TM	Training Manuals
TWT	Traveling Wave Tube
TX	Transmitter

USATECOM	U.S. Army Test and Evaluation Command
WLU	Weapons Locator Unit
XLRIP	Extended Low Rate Initial Production

INTRODUCTION

WHAT THE RADARS DO

- AUTOMATICALLY DETECT AND TRACK THE LAUNCH OF ROCKETS, ARTILLERY SHELLS, MORTARS
- TRACK MULTIPLE TARGETS SIMULTANEOUSLY
- TRANSMIT HOSTILE LAUNCH LOCATIONS TO THE TACFIRE DIRECTION CENTER (FDC) IN REAL TIME (OFTEN BEFORE SHELL LANDS)
- PROVIDE REGISTRATION OF FRIENDLY FIRE
- MEASURE ACCURACY OF FRIENDLY COUNTERFIRE DURING BATTLE
- AUTOMATICALLY DETECT AND ISOLATE FAULTS IN THE RADAR

WHY DID ARMY DEVELOP THESE RADARS?

- EARLIER SYSTEMS WERE ABLE TO LOOK AT ONLY ONE TARGET AT A TIME
- EARLIER SYSTEMS WERE MECHANICAL SCANNERS AND WERE MUCH LESS ACCURATE
- EARLIER SYSTEMS WERE RELATIVELY INEFFECTIVE
- EARLIER SYSTEMS REQUIRED CONSTANT OPERATOR AWARENESS TO ACCOMPLISH HOSTILE WEAPON LOCATION
- NO AUTOMATION WAS AVAILABLE

MISSION NEED

SUPPRESSION OF HOSTILE INDIRECT FIRE

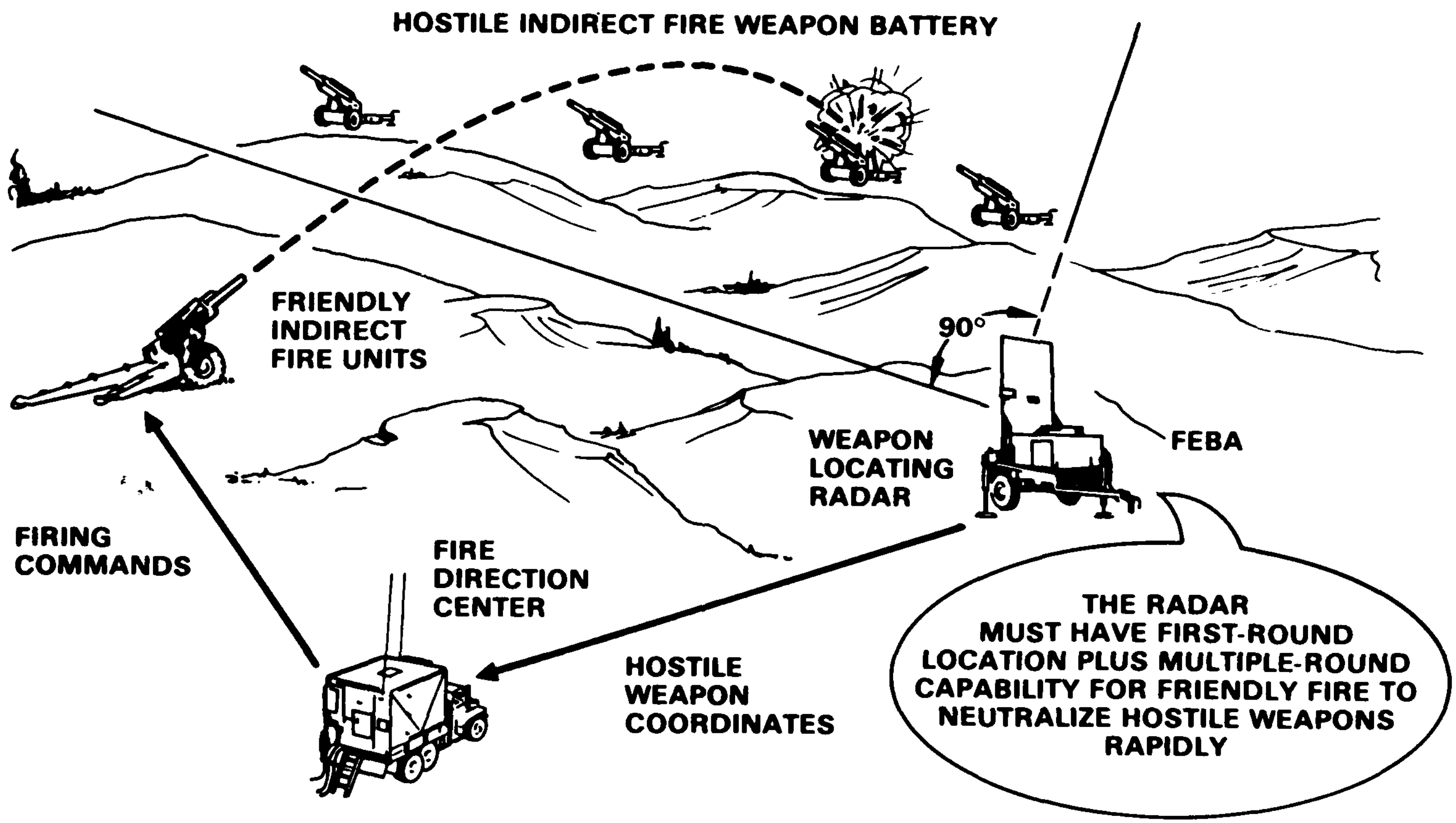
Powerful destructive results are achieved by artillery. In fact, indirect fire from artillery, rockets, mortars, and grenades has traditionally been responsible for most of the casualties among ground combat troops. In World War II, the vast majority of ground combat force casualties were caused by such indirect fire, with similar results in Korea and, to a lesser extent, in Vietnam.

The advantage of indirect fire weapons is the ability to fire from relatively protected lefilade positions, capitalizing on the principles of surprise and mass, while remaining generally undetected. To date, no effective capability to locate indirect fire artillery has existed. Direct observation, ranging by sound or flash, crater analysis, or old technology mortar locating radars have provided only limited capability. Such systems are imited in range, in sector coverage, in accuracy, and in dependability.

To be effective in today's highly mobile battlefield environment, a weapon locating ystem must locate hostile weapons quickly and accurately, even in the face of saturation rings in preparation for an attack. To be cost-effective, the system must have the widest ssible surveillance sector, with a 360-degree sector required for such special tuations as an insurgency environment or guerilla warfare.

In addition, a modern system must be resistant to electronic countermeasures, with ilt-in survivability features that ensure system operational performance in a hostile ttlefield environment.

HOSTILE INDIRECT FIRE WEAPONS MUST BE LOCATED AND SUPPRESSED TO CONTROL THE BATTLE



FIREFINDER RADARS AUDIT TRAIL

The figure presents an audit trail from the Department of Army Materiel Need Document for Weapons Locating Radars to the prime item development specification MIL-R-49145. The performance requirements indicated relate to the overall reliability, availability, and maintainability of the radar in the operational and storage modes. The performance requirements used in the audit trail are: radar detection; reliability; availability/maintainability; environmental conditions; and storage conditions. The performance requirements for the radar track well from the Materiel Need Document to the requirements and specifications called up for the radar in MIL-R-49145 (TPQ 36) and MIL-R-49360 (TPQ 37)

RADAR RAM AUDIT TRAIL FROM MATERIEL
NEED TO REQUIREMENTS/TEST

PERFORMANCE REQUIREMENT	TPQ-36 MATERIEL NEED	TPQ-37 MATERIEL NEED
RADAR DETECTION	CLASSIFED PERFORMANCE CAPABILITY	CLASSIFIED PERFORMANCE CAPABILITY
RELIABILITY	100-HOUR MTBF MIN 400-HOUR GOAL	90-HR MTBF MIN 180-HR GOAL
AVAILABILITY/MAINTAINABILITY	10-DAY (24-HOUR DAY) OPERATION WITH 1 HR/DAY SCHEDULED AND UNSCHEDULED MAINTENANCE	MISSION DURATION: 24 HR, OF WHICH 19 HR IS IN OPERATIONAL MODE; 5 HR IN TRAVEL AND MAINTENANCE MODE
ENVIRONMENTAL CONDITIONS	SYSTEM TO OPERATE IN: HOT-DRY; WARM-WET; COLD AND INTERMEDIATE CONDITIONS AR 70-38	SYSTEM TO OPERATE IN CATEGORIES 1-7, AR 70-38
STORAGE CONDITIONS	CONDITIONS OF STORAGE: TEMP; HUMIDITY; ALTITUDE; ONE-YR MIN, FIVE-YR GOAL	CONDITIONS OF STORAGE: HIGH TEMPERATURE, LOW TEMPERATURE

SYSTEM DESCRIPTION

The following figures shows the major elements of the AN/TPQ-36 and AN/TPQ-37 weapon locating radars.

AN/TPQ-36

The AN/TPQ-36 radar set consists of the AN/TPQ-36 antenna-transceiver group (A/T) and the common operations control group. The A/T contains the antenna, transmitter, receiver/exciter, and prime power unit, all mounted on a modified M116A1 3/4 ton trailer.

All electronics on the A/T are located in an enclosure above the azimuth bearing. It moves with the antenna when it changes sectors.

AN/TPQ-37

The AN/TPQ-37 radar set consists of the AN/TPQ-37 antenna-transceiver group (A/T) and the common operations control group. The A/T contains the antenna, transmitter, receiver/exciter, beam steering unit (BSU), RF detector, transmitter cooler, and trailer power distribution.

All of the components of the A/T are contained in a single trailer vehicle that can be quickly emplaced and displaced for transport.

The power distribution group, mounted on a 5-ton truck, includes the generator power transfer box and power cables. Power cabling permits 30.8 meter segregation between the antenna/transceiver and the power distribution group.

OPERATING CONTROL GROUP (COMMON SHELTER)

The operations control group contains the signal processor, digital computer, and all operator interface equipment. This includes a B-scope display, radios, line printer, weapon location unit, and the radar control switches and digital readouts.

A single operator directs the radar from the operations control group; the A/T is not manned. The design of the operation control group hardware is common for the AN/TPQ-36 and AN/TPQ-37 systems. The computer software for each system is unique.

THE AN/TPQ-36, COMPUTER-CONTROLLED WEAPON LOCATING RADAR

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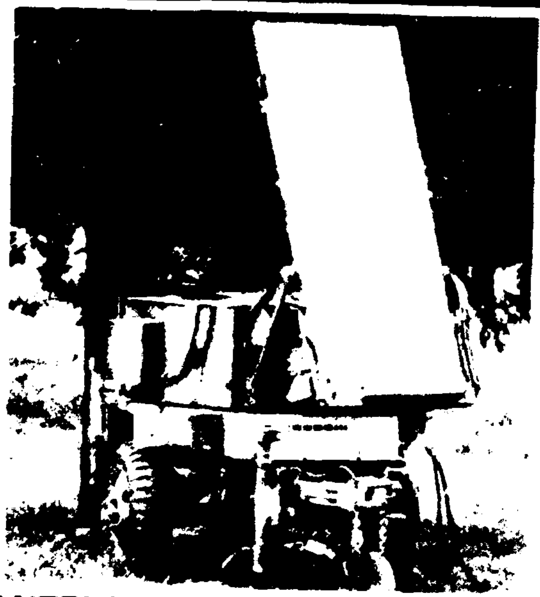

ANTENNA/TRANSCEIVER GROUP

- ELECTRONIC SCANNING
- RUGGED AND MOBILE
- SECTOR COVERAGE OF UP TO 90° FOR EACH ANTENNA POSITION
- FOUR 90° SECTORS PROVIDE 360° COVERAGE

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OPERATIONS CONTROL GROUP

- FULL COMPUTER CONTROL
- CLUTTER AND JAMMER REJECTION
- MULTIPLE FIRE CAPABILITY
- HIGH ACCURACY

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THE AN/TPQ-37, COMPUTER-CONTROLLED WEAPON LOCATING RADAR

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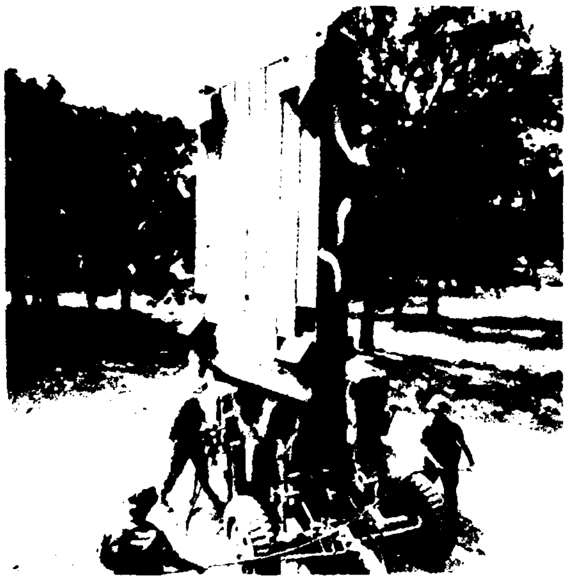

ANTENNA/TRANSCEIVER GROUP

- ELECTRONIC SCANNING
- RUGGED AND MOBILE
- SECTOR COVERAGE OF UP TO 90° FOR EACH ANTENNA POSITION
- LOW SIDELOBES

OPERATIONS CONTROL GROUP

- FULL COMPUTER CONTROL
- CLUTTER AND JAMMER REJECTION
- MULTIPLE FIRE CAPABILITY
- HIGH ACCURACY

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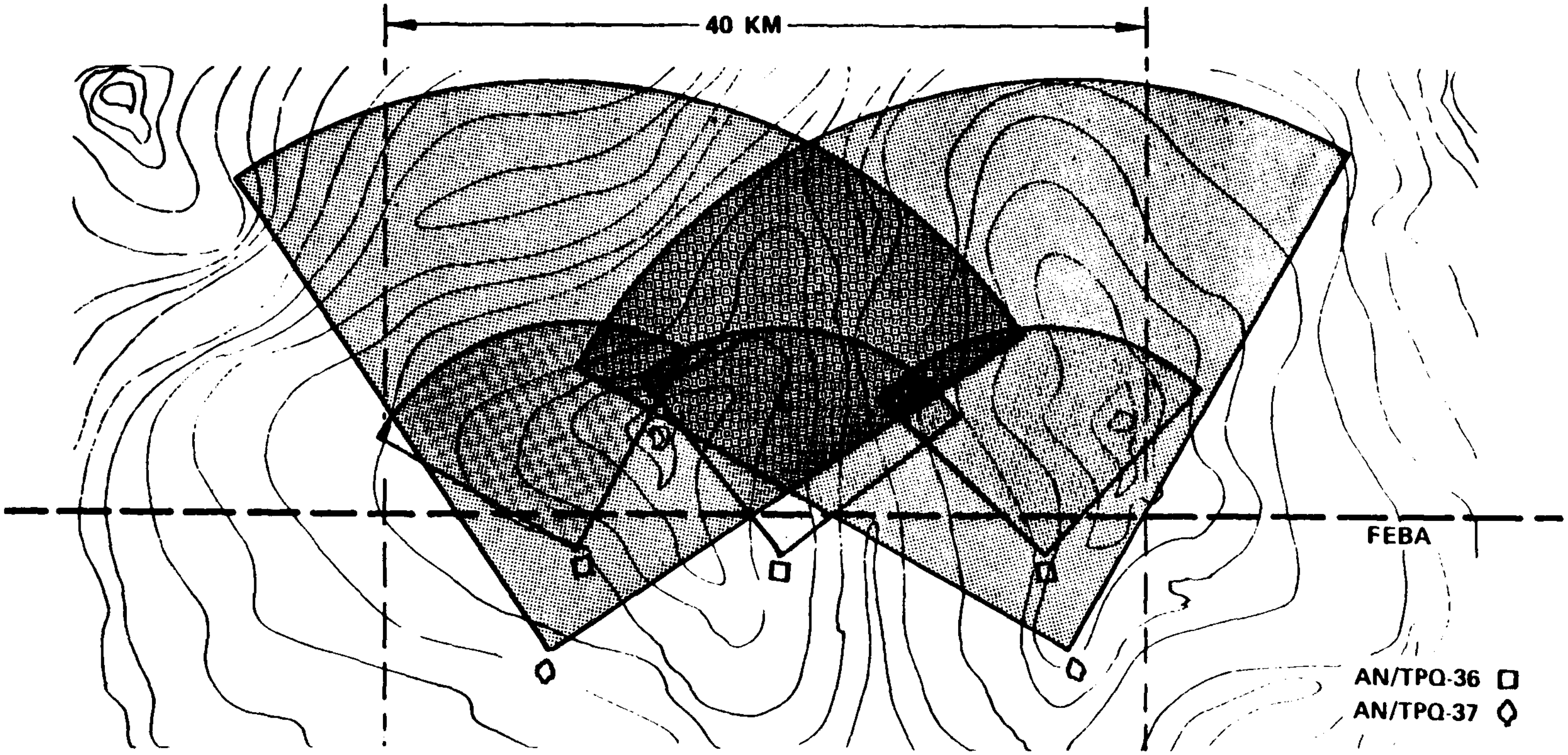
TYPICAL DIVISION LEVEL DEPLOYMENT

Two TPQ-37s and three TPQ-36s constitute a normal division complement of radars.



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COUNTER-BATTERY FIRE DEMANDS MODERN RADAR

Effective counter-battery fire requires a target acquisition capability that provides an accurate hostile gun location the first time the gun fires, and before it can adjust into a target or relocate.

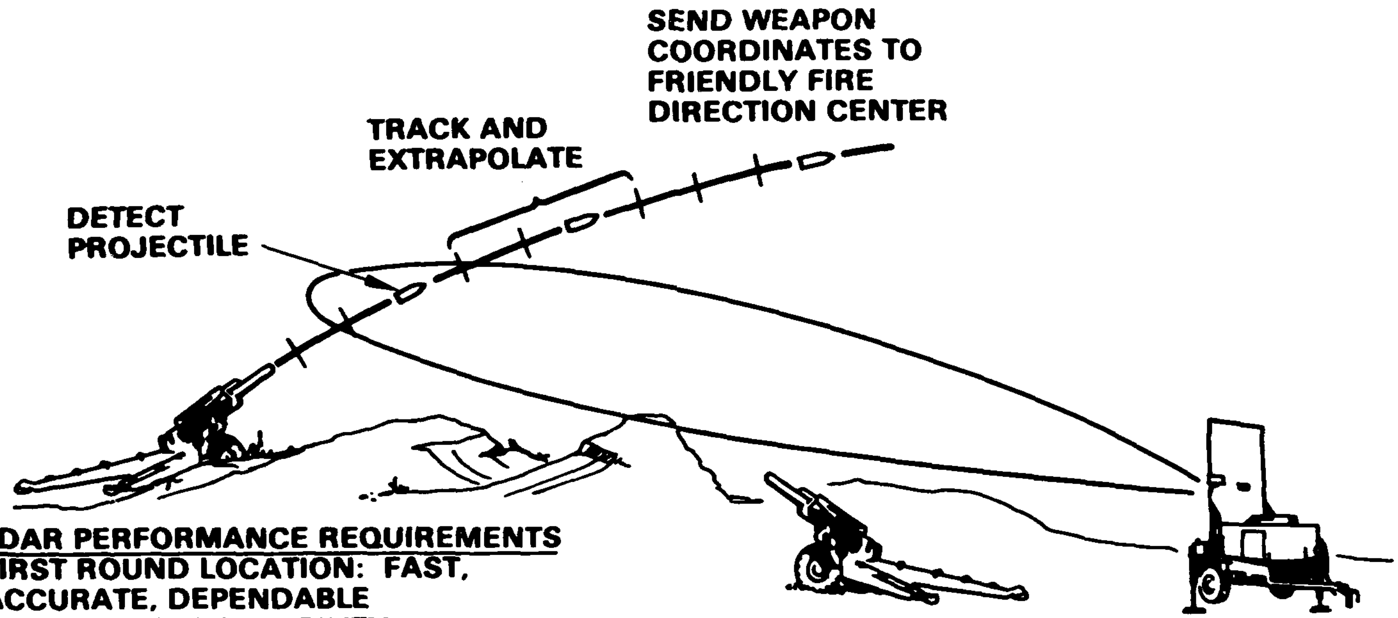
Often, enemy artillery will either adjust onto its target by successive bracketing, or with sufficiently accurate target information will fire several "fire-for-effect" volleys in quick succession. Ideally, counterfire should suppress the second and succeeding rounds. To approach this ideal, the radar must detect and locate the weapon within seconds--before the round lands--providing fast, accurate, dependable information to the Fire Direction Center.

The most demanding and critical period for a weapon locating radar is just prior to an enemy attack, when in unison all available weapons fire at pre-selected targets to soften the friendly lines.

During times of subdued hostile artillery activity, weapon locating radars must be able to provide surveillance of expanded sectors and must be able to accurately register and adjust friendly artillery.

To survive on the battlefield, the radar must be capable of being rapidly displaced, with high cross-country mobility. The radar must also be resistant to jamming, and should provide jammer location. Survivability, combined with ease of maintenance and high reliability, offers a weapon locating radar that is there when it is needed, providing fast, accurate, dependable information on hostile weapons before that first round lands.

EFFECTIVE COUNTER-BATTERY FIRE REQUIRES
A MODERN WEAPON LOCATING RADAR



RADAR PERFORMANCE REQUIREMENTS

- FIRST ROUND LOCATION: FAST, ACCURATE, DEPENDABLE
- MULTIPLE FIRE CAPABILITY
- EXTENDED COVERAGE
- ABILITY TO SUPPORT FRIENDLY FIRE
- PROVISION FOR COPING WITH CLUTTER AND JAMMING

OPERATIONAL REQUIREMENTS

- SURVIVABLE
- HIGHLY MOBILE
- RELIABLE
- MAINTAINABLE
- ALL-WEATHER CAPABLE

COMPUTER-CONTROLLED SCANNING

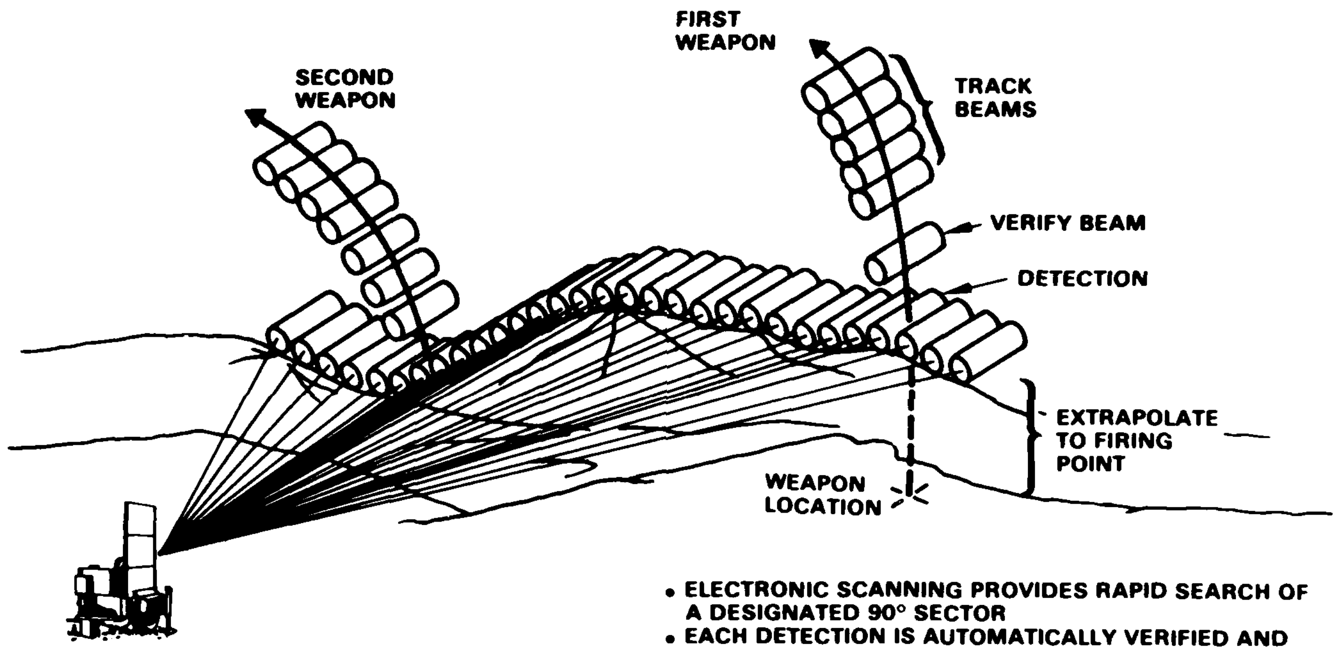
Under control of the radar's computer and signal processor, the AN/TPQ-36 and AN/TPQ-37 programs beams to search rapidly along the radar horizon, sweeping several times per second, searching for projectiles as they emerge above the mask. When a projectile is detected and a subsequent beam verifies the detection, track beams are programmed to follow the path of the projectile for a few seconds until sufficient data points are obtained for accurate extrapolation to the weapon location.

With electronic scanning, beams can be instantaneously positioned anywhere both vertically and horizontally within the radar sector, providing for continuation of search while a projectile is being tracked. Similarly, simultaneous tracking of several projectiles is possible while the search for new detections continues.

The capability to move beams so rapidly throughout the sector is provided by electronic beam positioning, shifting the phase to move the beam horizontally. The TPQ-36 changes frequencies for vertical movement, whereas in the TPQ-36, phase shifting is used. It is this same electronic scanning that enables the beams of the search fence to closely follow the terrain profile, providing early detection of even flat trajectory weapons, and minimizing the extrapolation distance. The result is accuracy sufficient for "fire for effect" counterfire.

Electronic beam positioning also allows step scanning rather than continuous scanning as in the motion of a mechanically-scanned radar. Step scan, together with a highly stable, coherent transmitter, allows the radar to achieve excellent clutter rejection. By thus filtering ground clutter returns and retaining signals from moving objects, the radar can operate effectively even in mountainous terrain.

COMPUTER-CONTROLLED ELECTRONIC SCANNING ENSURES
RAPID DETECTION, VERIFICATION, TRACKING AND
EXTRAPOLATION OF TRAJECTORIES



- ELECTRONIC SCANNING PROVIDES RAPID SEARCH OF A DESIGNATED 90° SECTOR
- EACH DETECTION IS AUTOMATICALLY VERIFIED AND CLASSIFIED
- PROJECTILE TRACK IS INITIATED WHILE SEARCH CONTINUES
- EACH PROJECTILE TRACK TAKES ONLY A FEW SECONDS
- MANY PROJECTILES CAN BE TRACKED SIMULTANEOUSLY

DETECTS WEAPONS UNDER BARRAGE FIRING

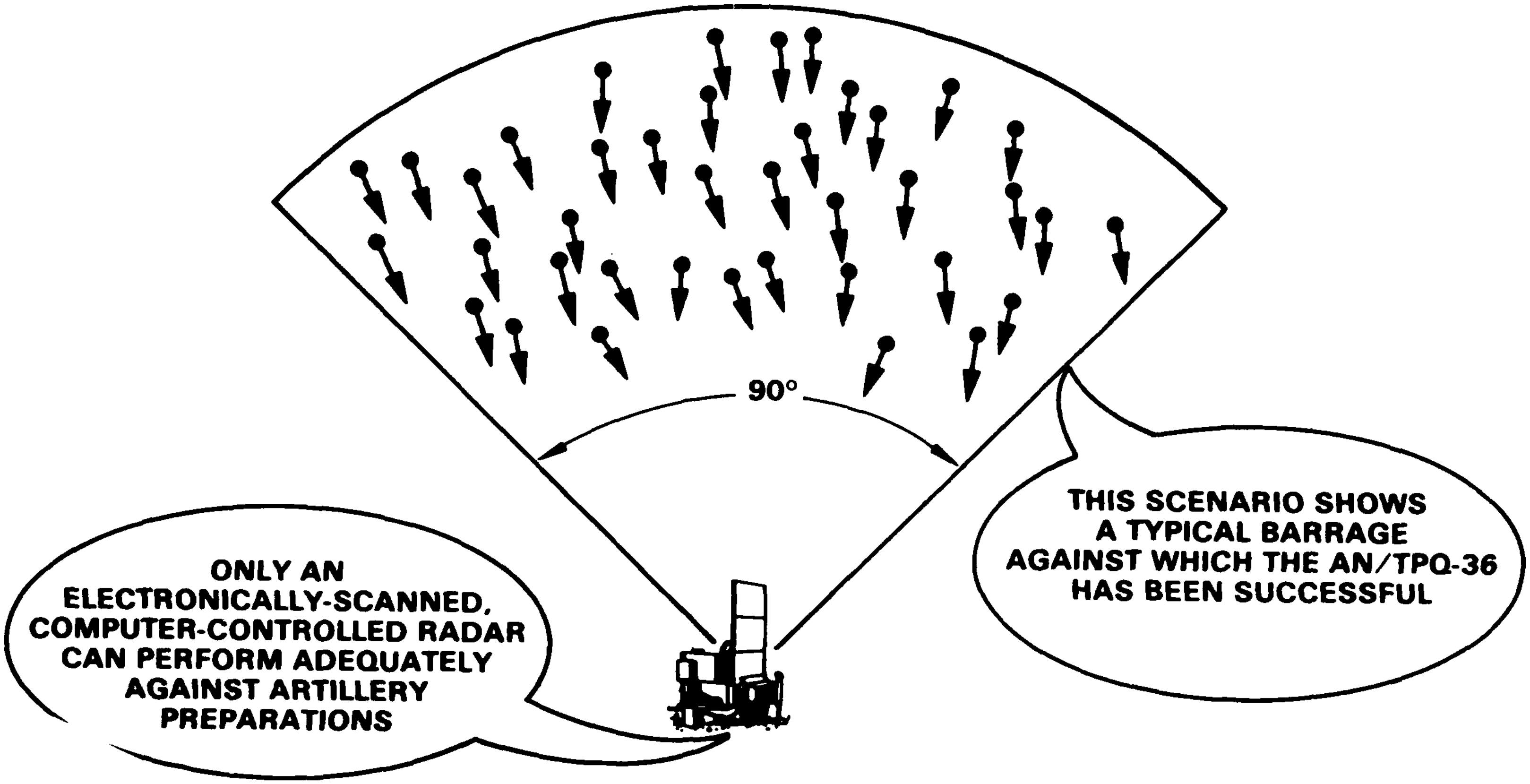
A weapon locating radar is put to its severest test under high volume artillery fire, for it is then that the enemy is probably preparing to launch an offensive. Older technology radars cannot cope with such barrage firing, quickly saturating and providing too many targets for a human operator using a B-scope, where the operator must make all decisions.

Unlike older systems, however, the radars are capable of handling extremely dense barrage fire without operator assistance. With its electronic scanning, the radars can switch their beams for search or track anywhere in the ninety-degree sector in microseconds. The high speed computer not only controls the placing of beams; it stores information from each radar return and then performs the trajectory fitting computation that provides the location of the hostile weapon.

In addition, a special automatic censoring capability implemented by the computer adapts the radar tracking capability to the high-density environment. With this capability, the radar devotes its time to tracking projectiles from weapons not previously located, avoiding repetitious locations of the same weapons.

Shown in the figure is a scenario for such high volume firing taken from one of the many radar tests using live mortar and artillery firing. The large number of different weapon positions fired on cue and continued firing for a limited period to determine the radar's capability under such barrage firing conditions. Results are classified, but the radar performed better than was required.

THE RADARS CAN PROVIDE WEAPON LOCATIONS
EVEN UNDER HIGH VOLUME BARRAGE FIRING



ALLOWS OFFSET OF FRIENDLY FIRE

Artillery is most effective when massed fire can be placed accurately and with surprise onto a hostile position. The radar can identify quickly, in one round, the impact point for friendly artillery. Moreover, this radar offers the unique capability of enabling surprise massed fires with economy of force.

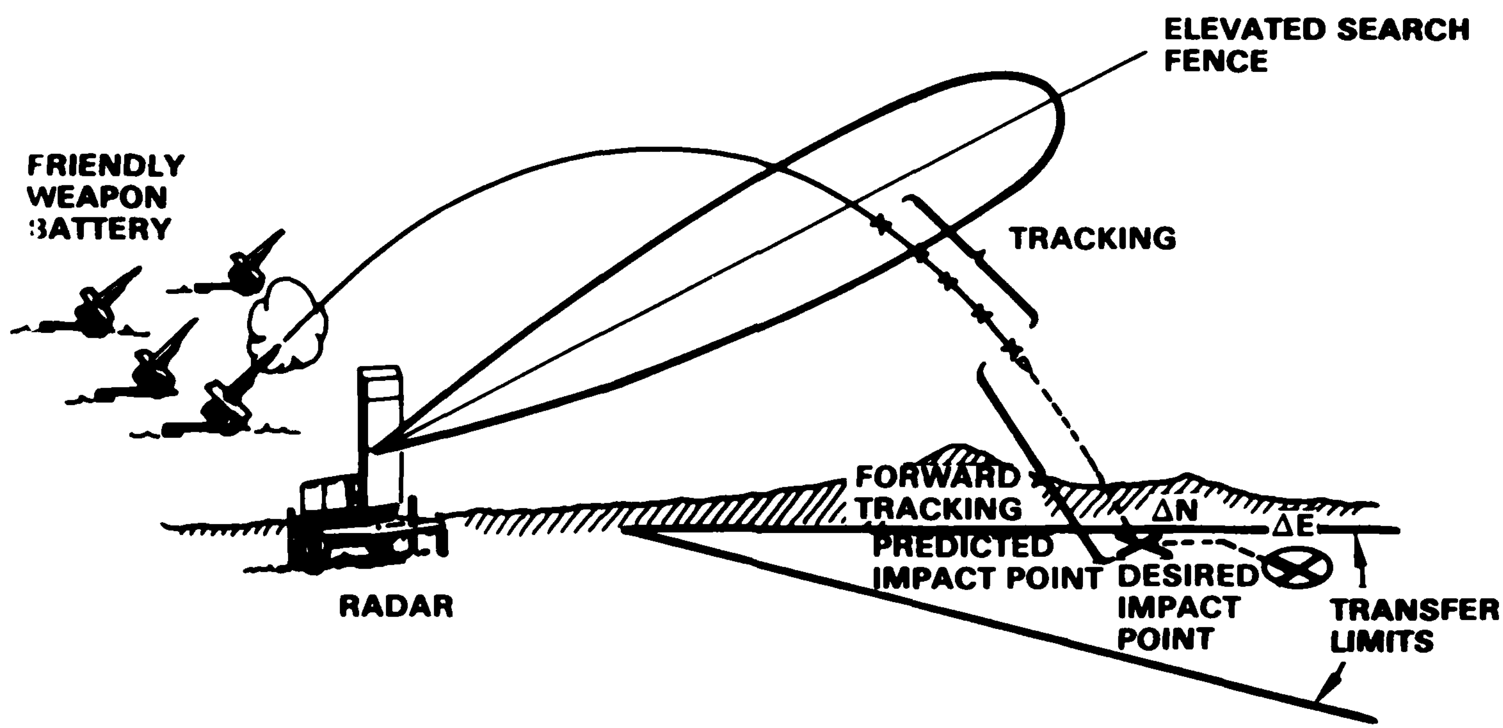
Because of the inherent accuracy and dependability of the radar, it can be used to adjust friendly fire for a number of weapons (and even from a number of different batteries) onto a single target. Each battery need fire only one round instead of numerous successively closer rounds.

This capability can be particularly useful during "Hipshoot" operations when emergency conditions may not permit reconnaissance of position or normal position preparation prior to firing.

As shown above, the location of the friendly weapon impact is determined by tracking the projectile and identifying the impact point, then providing this offset adjustment to the fire direction center for subsequent rounds. When these offsets are within the transfer limits of the desired impact point, the accuracy of the radar is sufficient to enable firing for effect, eliminating the need for any further adjustment rounds.

To mass fires from several batteries on a single target, the radar can provide such shifts within transfer limits to all batteries, which then can fire for effect using time-on-target techniques, combining massed fires with surprise.

ENABLES ACCURATE OFFSET ADJUSTMENT OF FRIENDLY FIRE
WITH ONLY ONE ROUND FIRED



TRACK DATA USED TO COMPUTE HOSTILE PROJECTILE PATH

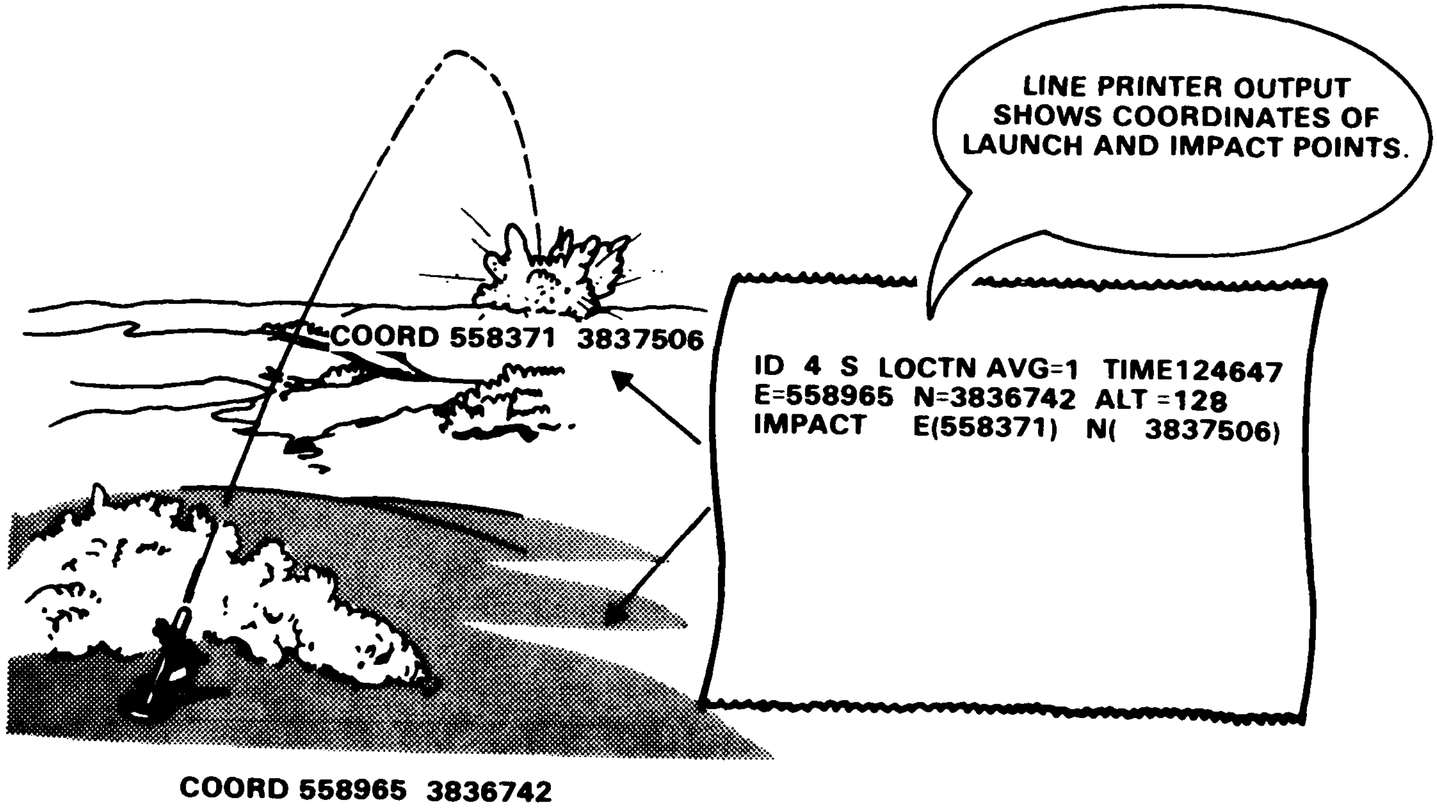
When hostile weapons are firing, it is often desirable to be able to associate projectile impact with the particular weapon(s) doing the firing. Thus, if some hostile rounds are fired at low value targets, the associated weapon locations may be ignored for a time and counterfire concentrated on those hostile weapons firing at higher value targets. The radar has the capability of determining the point of impact of hostile projectiles.

A hostile round may be detected in flight and tracked over the early portion (up leg) of the trajectory. The track data is then processed in a reverse sequence to obtain the location of the weapon. An additional step in the software obtains a forward solution for the impact point of the round.

The Hostile Impact submode can be enabled or disabled by the radar operator at any time during operation in the hostile mode. When this submode is activated, a third line is added to the normal two line strip printer message for hostile weapon locations, as shown in the figure. The third line gives the impact coordinates of a round fired from the hostile weapon position described by the first two lines.

The capability is of particular importance during multiple weapon firings when counterfire priorities must be established, or when a commander's counterfire capabilities may be limited. It provides the information required by a commander to maximize the effectiveness of his counterfire resources.

TRACKING DATA CAN BE USED TO EXTRAPOLATE THE HOSTILE PROJECTILE'S PATH TO THE INTENDED TARGET AREA



SPECIAL MODE PERMITS REGISTRATION OF FRIENDLY FIRE

For high accuracy, artillery should periodically be registered to determine the weapon-projectile-fuse performance under existing conditions. The radars provide the most accurate means of such registration, and offer the potential of registration using less ammunition than by standard means.

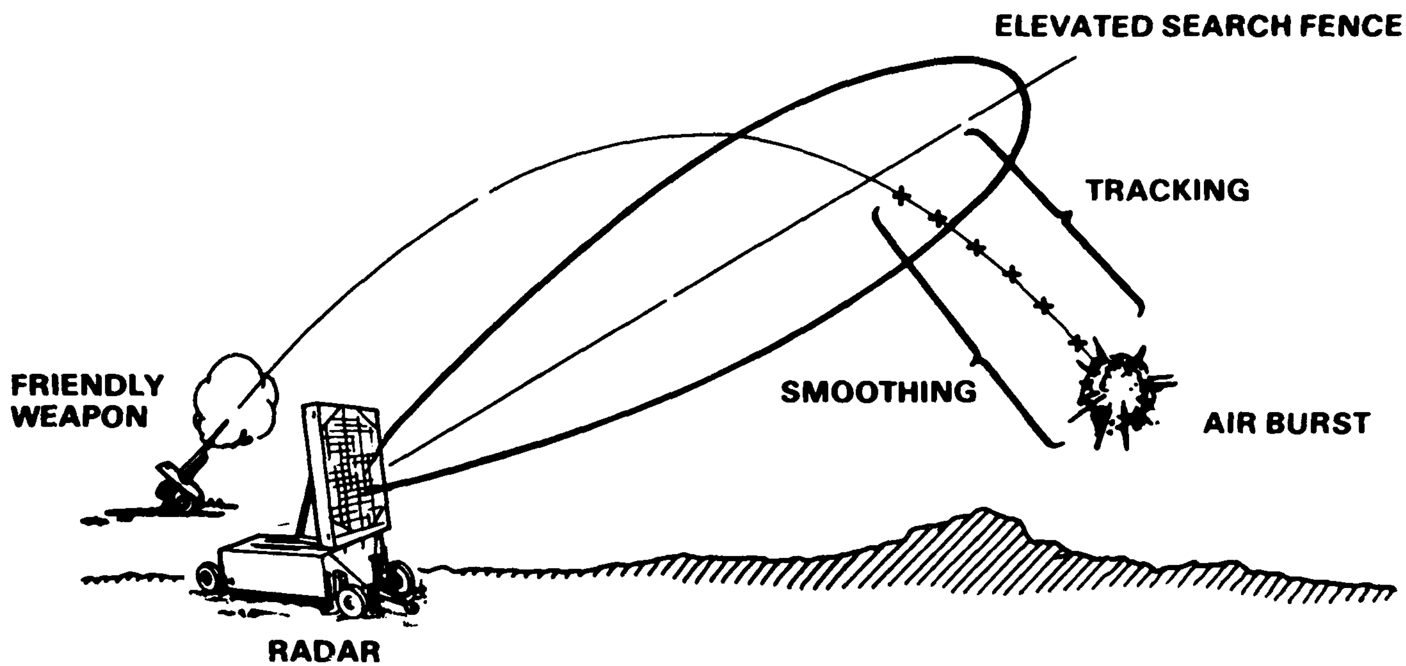
For adjustment of friendly fires on either unobserved or observed targets, the radars accuracy again offers a cost-effective solution, and adds the dimension of surprise massed fires by adjusting on offset targets prior to fire for effect.

To accomplish registration and adjustment of friendly fires, the radars have multiple modes, including; artillery datum plane registration; artillery air burst registration and artillery impact predict. In the registration modes, the radar provides precise coordinates and altitude of a point in space along the friendly trajectory or the coordinates of an air burst, allowing use of registration data in subsequent firings.

In the impact predict modes, the radar extrapolates the trajectory of the friendly fire for effect.

When the friendly fire mode is selected, the computer automatically positions the radar and sets up a search fence to intercept the projectile path after apogee. The radar is programmed to acquire the friendly projectile and track it down to the registration point, as limited by the optical mask and ground clutter returns. The figure shows a typical friendly fire trajectory with air burst registration.

A SPECIAL MODE PERMITS REGISTRATION
AND ADJUSTMENT OF FRIENDLY FIRE



MOBILITY

The radar system's tactical effectiveness as well as its survivability are enhanced by the fact that it can be emplaced in the most tactically advantageous position.

It can be located at unimproved sites, and because of its land clutter rejection capability does not require high nearby terrain to mask clutter at longer ranges. Thus it can be located on high ground where it is capable of detecting close-in pop-up targets.

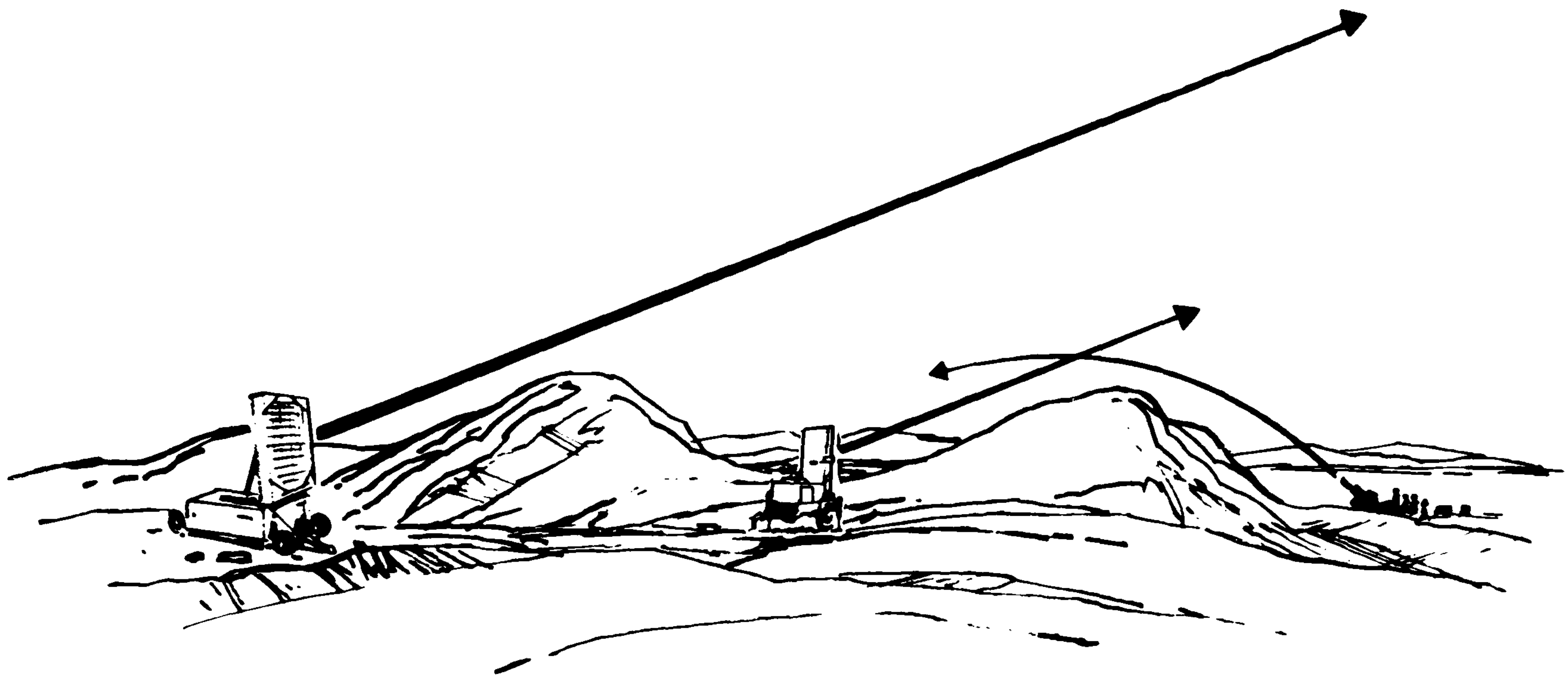
Generally, the site selected need only have adequate drainage and have a ground slope of less than seven degrees. The shelter can be entrenched, sandbagged, or located among trees in a protected area.

The antenna-transceiver group has mechanical jacking provisions with independent extension capabilities adequate for leveling on a seven degree slope.

The operations control group does not require leveling for operation on slopes, whether installed on a carrier vehicle or separately deployed.

The TPQ-36/TPQ-37 are complementary; *TPQ-37 is long range, placed far back from enemy;* TPQ-36 is smaller, can be emplaced/displaced more quickly.

THE HIGH MOBILITY OF AN/TPQ-36 COMPLEMENTS
THE LONG-RANGE OF THE AN/TPQ-37



BOTH RADARS ARE SIMPLE TO OPERATE

When the radar set determines a hostile location, an alarm sounds and the "Display Next Location" switchlamp on the weapons location unit (*WLU*) lights. The operator presses the "Display Next Location" switchlamp and the WLU map rotates to the northing coordinate of the weapon and a lamp lights under the site at the easting coordinate.

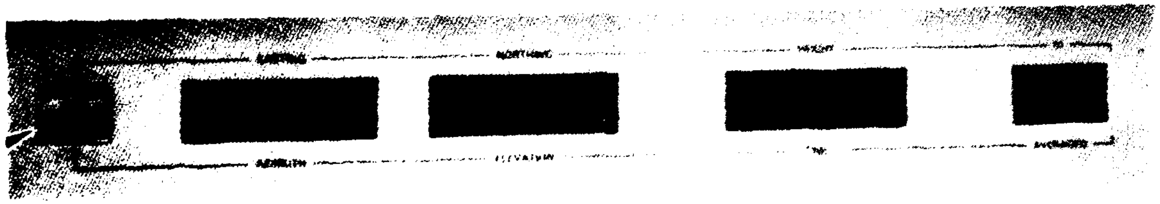
The lighted spot marks the intersection of the weapon trajectory with the reference datum plane. The operator must then height correct the weapon location. With digital maps, this is performed by the computer.

When the weapon height has been corrected either automatically or by the operator, he places the location data in permanent storage by pressing the "Enter Location" switchlamp. The location is then assigned an ID number by the computer and then stored location data and ID are printed by the line printer and displayed on one half of the B-Scope.

If digital transmission of the location data is to be performed, the operator presses the switchlamp to initiate preparation of a digital message. Otherwise, the location data is transmitted by voice over either radio or landline.

A trained operator can accomplish this procedure in seconds. The location of indirect fire hostile weapons can often be given to the Fire Direction Center while the round is still in the air.

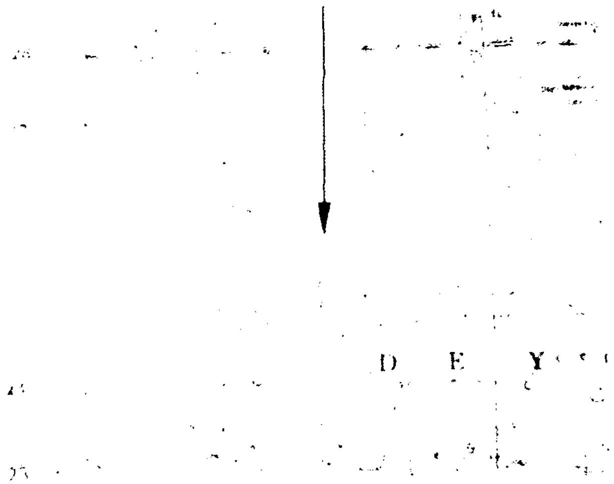
THE BASIC OPERATING PROCEDURE
IS VERY SIMPLE



DIGITAL
READOUT OF
WEAPON
LOCATION

COMPUTER POSITIONED
SPOT SHOWS WEAPON
LOCATION

OPERATOR ENTERS HEIGHT CORRECTION



LOCATION OF HOSTILE WEAPON IS FULLY AUTOMATIC WITH MINIMAL OPERATOR ACTION

OPERATOR TASKS	COMPUTER FUNCTIONS	
NONE	• GENERATES SEARCH BEAMS	
NONE	• DETECTS TARGET	
		• OUTPUTS TARGET LOCATION
NONE	• GENERATES VERIFICATION BEAM; CONTINUES SEARCH	• PERFORMS HEIGHT CORRECTION (IF NECESSARY) DIGITAL MAPS ELIMINATE OPERATOR ACTION
NONE	• GENERATES TRACK BEAMS; CONTINUES SEARCH	
NONE	• EXTRAPOLATES TO DATUM PLANE	
AS REQUIRED	• ALERTS OPERATOR	• RELAYS TARGET LOCATION TO FIRE DIRECTION CENTER
NONE	• EXTRAPOLATES TO REVISED ALTITUDE	
NONE	• CHECKS DATA FOR ZONE, PRIOR LOCATION, ETC.	• CONTINUES TO PERFORM REQUIRED TASKS (HEIGHT CORRECTION, ENABLING OF IMPACT POINT EXTRAPOLATION, ETC.) DIGITAL MAPS ELIMINATE OPERATOR ACTION
NONE	• DETECTS SECOND TARGET, REPEATS VERIFICATION, TRACK PROCESS	

OUTPERFORMS MECHANICALLY SCANNED RADARS

Manually operated, mechanically scanned radars are severely constrained by required operator actions in the projectile detection process. In these older technology radars constant operator vigilance and attention to the display are essential. The penalty paid for this vigilance is operator fatigue that results in undetected projectiles and unlocated weapons.

The radars automatically detect projectiles, compute weapon locations and store the track data in computer memory. No operator action is required in the projectile acquisition or location computing process. The result is a major improvement in weapon location capability. Even when the radar is temporarily unattended, the system continues to detect, process and store weapon locations, retaining them for operator review.

Mechanical scan radar beams are at fixed elevations. For proper location, a projectile must cross two or more of these fixed beams. With the Firefinder Radars beams are positioned not only along the terrain, but all along the path of the projectile, providing numerous data points for accurate extrapolation. The computer then calculates the weapon position, automatically adjusting for altitude.

The radars provide artillery location, multiple weapon location, automatic altitude correction and high probability of location, all of which only an automatic radar can offer. These combine with the extended area coverage to yield greater cost effectiveness.

FIREFINDER COMPARISON TO MANUALLY-OPERATED, MECHANICALLY-SCANNED RADARS

	MECHANICAL-SCAN RADARS	FIREFINDER RADARS
SCAN CONCEPT	SEQUENTIAL SCANNING AT TWO FIXED ELEVATIONS	RAPID SCANNING USING VARIABLE ELEVATION
SECTOR	25° OR 40°	90°
OPERATOR ACTIONS	CONTINUOUS VIGILANCE TO DETECT PROJECTILES	ALERTED TO LOCATION BY VISUAL AND AURAL SIGNALS
MULTIPLE WEAPON CAPABILITY	NO	YES. SIMULTANEOUSLY
ARTILLERY LOCATION	ONLY IF THE PROJECTILE CROSSES BOTH UPPER AND LOWER BEAMS	AUTOMATIC TRACKING AND LOCATING
WEAPON ALTITUDE DETERMINATION	MANUAL, IF ANY	AUTOMATIC OR SEMIAUTOMATIC
SPEED OF LOCATION	DEPENDENT ON SKILL OF OPERATOR	IN SECONDS

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FIREFINDER RADARS PHYSICAL DESCRIPTION

	TPQ-36	TPQ-37
PRIME POWER	10,000 WATTS	45,000 WATTS
WEIGHT		
- TRAILER	3,000 LBS	10,000 LBS
- SHELTER	2,500 LBS	2,500 LBS
HEIGHT	12 FT	17 FT
NUMBER OF PARTS ELECTRICAL/ ELECTRONIC	21,938	61,561

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TPQ-36/37 COMPONENT PART COUNT

	DIODES	TRANS-ISTORS	ICs MONO	3) ICs HYBRID	CAPS	RES-ISTORS	MAG-NETICS	CABLES	1) CON-NECTORS	PWBs	RF& M/W	5) OTHER	TOTAL
COMMON SHELTER	798	251	5421	14	5045	2550	176	86	172 312	312	-	453	15,590
TPQ-36 TRAILER	688	136	770	108	1469	1851	177	164	329 25	150	133 64 4)	284	6,348
TPQ-37 TRAILER	2737 5400 2)	287	2064	123	3670	18063 1800 2)	762	3148	6296 150 720 2)	150	175 2) 3)	426	45,971

SUMMARY - ELECTRICAL/ELECTRONIC PARTS

AN/TPQ-36	21,938
AN/TPQ-37	61,561

1) First number cable connectors; second number card edge connectors

2) 360 phase shifter submodules contain 5400 diodes, 720 connectors and 1800 resistors which are included in the respective part totals

3) Thick and thin film resistors and chips in Hybrid ICs and thick film capacitors in TPQ-37 phase shifter submodules not included in part count

4) TPQ-36 phase shifters each contain one coil

5) Mechanical parts not included

TPQ-36/37 TRAILER/SHELTER CABLES

NO. OF CABLES	1 POWER 1 SIGNAL	
VOLTAGE RATING	600 VRMS	
TEMP RANGE	-55°C TO +72°C	
NO. OF WIRES	POWER 5 # 12 WIRES	
	SIGNAL 57 TOTAL WIRES 2 RG-223 PER MIL-C-17 COAX 2 TWISTED PAIR-SHIELDED JACKETED #30AWG 14 TWISTED PAIR #24AWG 23 SINGLE #20AWG	
KIND OF INSULATION	CONDUCTORS	MIL-W-16878/17
	FILLERS	MIL-C-13777
	BARRIER TAPES	MIL-C-13777
	CABLE SEPARATOR	MIL-C-13777
	EXTERNAL SHEATH	POLYCHLOROPRENE, 2 LAYERS REINFORCED MIL-C-13777
KINDS OF SIGNALS	TIMING VIDEO DIGITAL	
KIND OF CONNECTORS	SIGNAL CIRCULAR MIL-C-22992 CLASS R INSERT: NEOPRENE RUBBER	

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PROGRAM SUMMARY

AN/TPQ-36

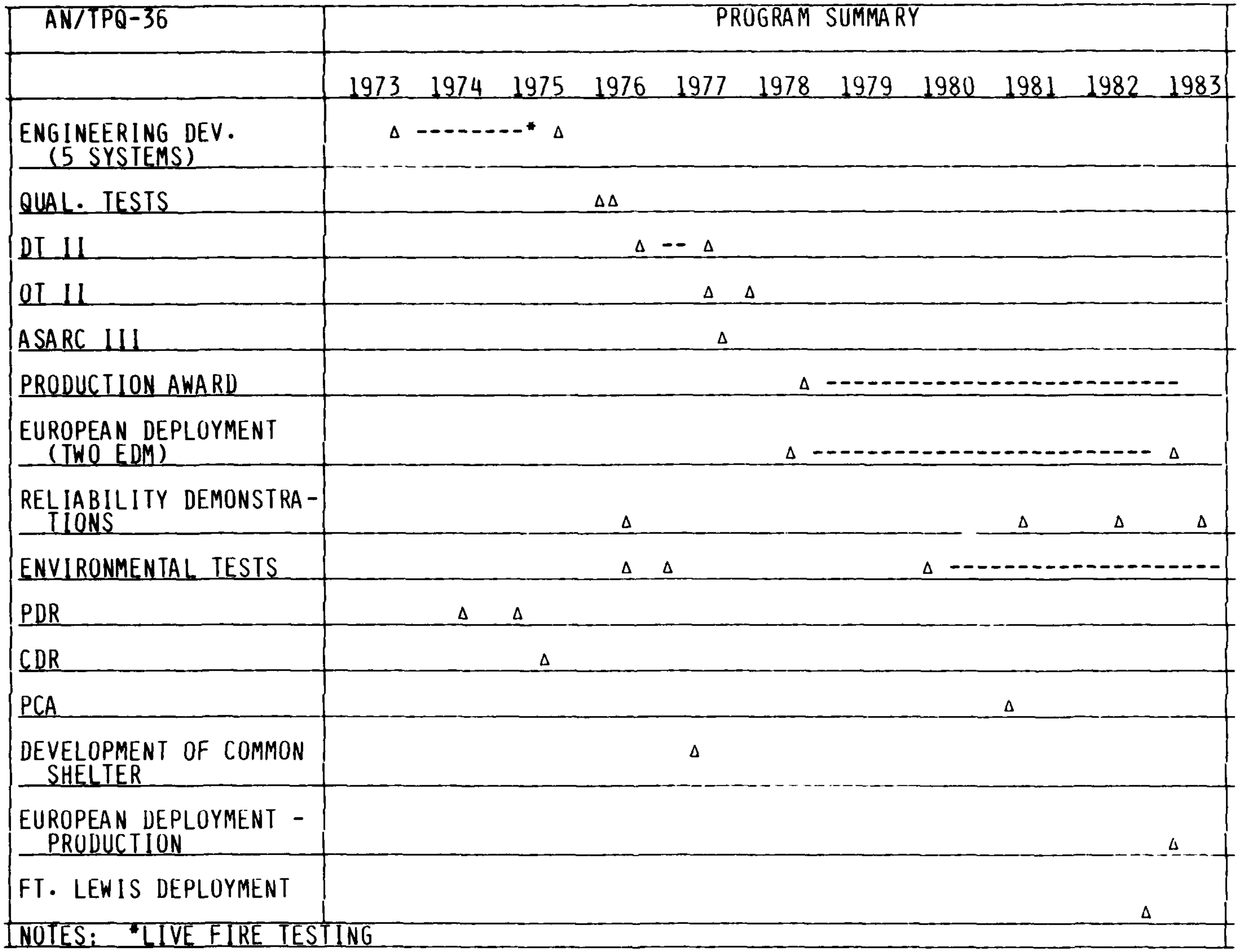
The AN/TPQ-36 program began with competitive procurement of engineering development in 1973. Competing contractors each made proposals to Army to meet R&M requirements. The AN/TPQ-36 completed qualification in 1976, and has successfully met its technical, reliability and maintainability requirements thus far. Full-scale production has been underway since 1978 for the U.S. Army and U.S. Marines in a multi-year production program. Deployment was initiated in 1978.

AN/TPQ-37

The AN/TPQ-37 program began with dual advanced development awards in 1972. Each contractor built one demonstration model. After tests of both competing contractors' radars in live fire tests, and completion of DT1/OT1, final selection of contractor was made in mid-1976. This led to a contract award for LRIP at the end of 1976, without a qualification program. Production deliveries began in 1979, with deployment in 1980.

Combined AN/TPQ-36 and AN/TPQ-37 Development

Advanced development effort was performed in the AN/TPQ-37 program only. Engineering development effort was performed in the AN/TPQ-36 program only.


AN/TPQ-36
PROGRAM SUMMARY
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983
ENGINEERING DEV. (5 SYSTEMS)
QUAL. TESTS
DT II
OT II
ASARC III
PRODUCTION AWARD
EUROPEAN DEPLOYMENT (TWO EDM)
RELIABILITY DEMONSTRATIONS
ENVIRONMENTAL TESTS
PDR
CDR
PCA
DEVELOPMENT OF COMMON SHELTER
EUROPEAN DEPLOYMENT - PRODUCTION
FT. LEWIS DEPLOYMENT
NOTES: *LIVE FIRE TESTING

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AN/TPQ-37(1)	PROGRAM SUMMARY											
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
ADVANCED DEVELOPMENT AWARD COMPETITIVE	Δ											
CONTRACTOR TESTS AT FORT SILL			* Δ	Δ								
DTI/OTI				Δ	Δ							
SELECTION OF WINNER					Δ							
ASARC II/ASARC III					Δ							
CONTRACT AWARD LRIP						Δ ----	----	----	----	----		
PDR	Δ ----	----	----	----	----	----	----	----				
CDR										Δ	Δ	
ENVIRONMENTAL TESTS				Δ	Δ			Δ ----	----	----	----	
PDR		Δ	Δ									
CDR			Δ					Δ				
PCA									Δ			
DELIVERIES LRIP AND EXTENDED LRIP								* Δ ----	----	----	----	----
DT/OT III									Δ	Δ		
ASARC IIIA										Δ		
FULL SCALE PRODUCTION										Δ		
DEPLOYMENT AT FT. HOOD									Δ			
DEPLOYMENT IN EUROPE											Δ	
RELIABILITY DEMONSTRATIONS										Δ		Δ
ENVIRONMENTAL TESTS										Δ Δ	Δ ----	----
DEVELOPMENT OF COMMON SHELTER					Δ							

NOTES: (1) WENT FROM AD TO PRODUCTION (*) LIVE FIRE TESTS

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MEASURES OF SUCCESS

AN/TPQ-36 HAS EXTENSIVE TEST HISTORY

Because of the worldwide and diverse environments in which the AN/TPQ-36 must perform, the radars were subjected to an extensive test program, as shown in the figure. Tests have stressed the ability of the radar to accomplish its basic mission of locating live artillery. They have been conducted in deserts, rain, mountains and flatlands. Specific tests have validated required mobility and have shown the AN/TPQ-36 performance superiority in comparative evaluations with other proposed concepts.

Each of the production radars is tested for performance under live fire test conditions. Selected radars in production are tested for numerous technical performance capabilities, including reliability, maintainability, interchangeability, humidity, dust, vibration, and shock.

Extensive testing of the AN/TPQ-36, expending over 50,000 rounds of ammunition, was used to validate the capability of the radar to locate hostile weapons with reliable, dependable battlefield performance. These tests provided a close approximation to actual battlefield conditions.

AN/TPQ-36 RADARS HAVE BEEN TESTED IN MANY WAYS AND ENVIRONMENTS FOR OVER 5 YEARS

1975	INITIAL LIVE FIRE TESTS	DETERMINE MORTAR LOCATING CAPABILITY: DESERT; SUMMER
1976	HWLS/TPQ-36 COMPARATIVE EVALUATION	DETERMINE ARTILLERY LOCATING CAPABILITY FOR U.S. MARINE CORPS: DESERT
1976	MOBILITY TESTS	VALIDATION OF SYSTEM MOBILITY: DESERT; WINTER
1976	RAIN TESTS	VALIDATE RF PROPAGATION PERFORMANCE UNDER HEAVY RAIN CONDITIONS: SEMITROPICAL
1976	ENVIRONMENTAL TESTS	TEST CAPABILITY UNDER CONDITIONS OF DUST, HUMIDITY, TEMPERATURE, VIBRATION, ETC.
1976-77	DEVELOPMENT TEST II	VALIDATE DEVELOPMENT SUCCESS AND SYSTEM CAPABILITY: WINTER
1977	OPERATIONAL TEST II	VALIDATE UTILITY AND CAPABILITY UNDER FIELD OPERATIONAL CONDITIONS: DESERT AND MOUNTAINS
1979	HIGH DENSITY FIRING EVALUATION	VALIDATE CAPABILITY UNDER BARRAGE FIRING CONDITIONS
1980	PRODUCTION ACCEPTANCE TESTS	VALIDATE PERFORMANCE OF PRODUCTION SYSTEMS: IN-PLANT

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AN/TPQ-37 HAS BEEN TESTED IN MANY ENVIRONMENTS

A successful weapon locating radar must be capable of operating in widely diverse environments, involving extremes of topography and climate. Recognizing this need, the U.S. Army has subjected the AN/TPQ-37 radars to an extensive test program. Tests conducted in all types of terrain and weather have stressed the ability of the radar to accomplish its basic mission of locating live artillery. Specific tests have validated required mobility and have shown the AN/TPQ-37's performance superiority.

Each of the production radars is tested for performance under live fire test conditions. Selected radars in production are tested for numerous technical performance capabilities, including reliability, maintainability, interchangeability, humidity, dust, vibration, and shock.

Specific testing emphasized the operational environment and focused on the suitability of the AN/TPQ-37 in emplacement, initialization, march order, and system operation with U.S. Army crew and maintenance personnel. Extensive use of live fire testing with U.S. Army personnel operating the system has validated the capability of the radar to locate hostile weapons with reliable, dependable battlefield performance.

Strong emphasis was placed on the ability of the system to deal with "barrage fire" conditions. Certain sections of Operational Test III conducted during 1980 ensured that the AN/TPQ-37 will provide the field commander with weapon position location where he wants it and when he wants it for effective management of his tactical resources.

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AN/TPQ-37 RADARS HAVE BEEN TESTED IN MANY ENVIRONMENTS FOR OVER 6 YEARS

974-75	INITIAL LIVE FIRE TESTS	DETERMINE ARTILLERY LOCATING CAPABILITY
977	ADDITIONAL LIVE FIRE TESTS	VALIDATE PERFORMANCE OF REFURBISHED DEVELOPMENT SYSTEM
979	LIVE FIRE TESTS	VALIDATE PERFORMANCE OF FIRST PRODUCTION AN/TPQ-37
979	DEVELOPMENT TEST III	DETERMINE BOUNDARY OF LRIP PERFORMANCE ENVELOPE
980	OPERATIONAL TEST III	VALIDATE CAPABILITY DURING BARRAGE FIRING UNDER FIELD CONDITIONS
980-81	ENVIRONMENTAL TESTS	TEST CAPABILITY UNDER TEMPERATURE, VIBRATION, HUMIDITY, DUST, ETC

THE RADARS ARE SIMPLE TO OPERATE AND MAINTAIN

Because of the system's high degree of automation in both the location and processing of hostile weapon locations, the radar functions are easily accomplished by a single operator. The operator can perform effectively for long periods of time, only checking the radar performance without tiresome monitoring of radar returns on a scope. The system even continues to perform automatically during periods in which the operator may be absent. Procedures are simplified and the hardware is designed for use by personnel with minimal skill levels.

Studies by the U.S. Army to determine the aptitude requirements for operators have revealed that operation is so simple that special electronics or radar aptitudes are not required and individuals with normal mechanical skills can be taught to operate and perform crew level maintenance on the radars.

THE RADARS ARE SIMPLE TO OPERATE AND MAINTAIN

- RADAR FUNCTIONS ARE ACCOMPLISHED BY A SINGLE OPERATOR
- SYSTEM CAN PERFORM AUTOMATICALLY EVEN WHEN OPERATOR IS ABSENT
    - TPQ-36 - EIGHT MAN CREW
    - TPQ-37 - TWELVE MAN CREW
- SPECIAL ELECTRONICS OR RADAR APTITUDES ARE NOT REQUIRED FOR OPERATION

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TPQ-36 AND TPQ-37 MEASURES OF SUCCESS SUMMARY

TPQ-36 RELIABILITY/MAINTAINABILITY

1. INITIAL FIELD RESULTS ** DEMONSTRATED 70 HOUR MTBF, (350 HOURS, 5 FAILURES). THIS IS 90% OF MEASURED LABORATORY MTBF
2. EACH FAILURE WAS REPAIRED USING THE INTENDED MAINTENANCE PROCEDURES

TPQ-37 RELIABILITY/MAINTAINABILITY

1. CONTRACTOR ACCEPTANCE TESTS PASSED, CONTRACTOR ACHIEVED 100 + HOUR MTBF, EXCEEDING CONTRACT
2. SYSTEMS HAVE 2 YEARS IN FIELD, ACHIEVE AVERAGE 50 HOUR MTBF *
3. TIMELINESS IN CORRECTING FIELD PROBLEMS WAS DEMONSTRATED BY CONTRACTOR RESPONSE TO CREATE DESIGN MODIFICATIONS
4. FIELD MEASURED MTBF WAS 50% OF LABORATORY MEASURED MTBF, HIGHER THAN USUALLY OBSERVED

* BASED ON 20 HOUR POWER ON AVERAGE PER WEEK

** OFFICIAL FIREFINDER FIELD DATA COLLECTION REPORT

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RELIABILITY AND MAINTAINABILITY REQUIREMENTS

AN/TPQ-36 CONTRACT GOALS/REQUIREMENTS FOR RELIABILITY

PROGF PHASE	TYPE CONTRACT	MTBF GOAL (HR)	MTBF REQUIREMENT (HR)
ENGI ERING DEVE PMENT (ED)	COST PLUS	400	100
	SUBSEQUENT TO ED THE SHELTER WAS REDESIGNED TO PROVIDE COMMONALITY WITH AN/TPQ-37		
FULL- LE PRODU ON	FIXED PRICE		100*

*A TEMPORARY ACCEPTANCE CRITERIA OF 75 HOURS WAS SET, WITH FIELD MODS REQUIRED. THE REQUIREMENTS FOR PRODUCTION WERE AS FOLLOWS:

MTBF = 150 HOURS (LOTS 1-4) 0°; 0_1 = 100
MTBF = 200 HOURS (LOTS 5-7) 0°; 0_1 = 100

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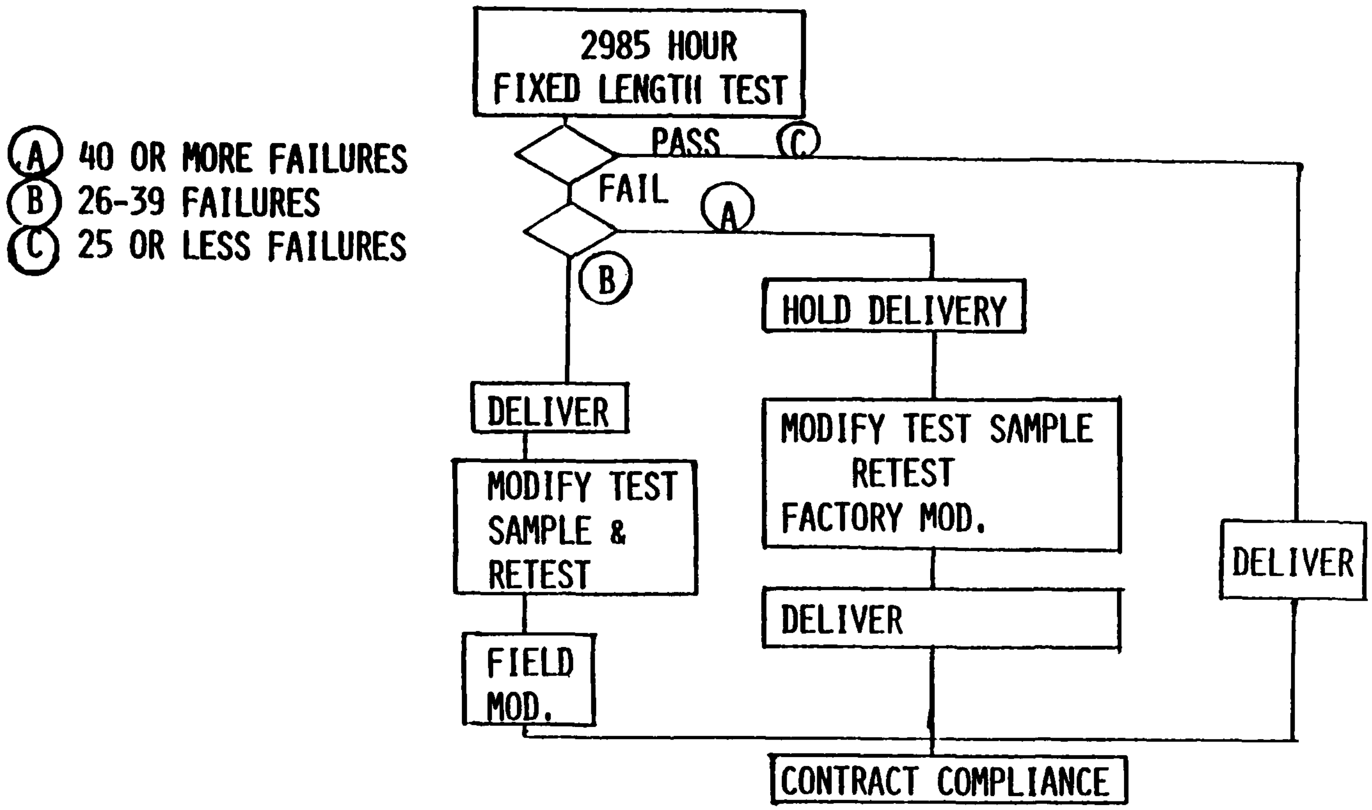
AN/TPQ-36 RELIABILITY ACCEPTANCE CRITERIA

In order to expedite use of AN/TPQ-36 radars in the field, a special arrangement was made to allow for an MTBF below specification requirements, but above 75 hours.

A 2985-hour fixed-length test, involving three radars, was to be conducted. With 25 or less failures, deliveries would be made in full contract compliance. With 26-39 failures deliveries could begin, but the test sample would have to be modified and retested to pass. These mods would then be installed in the field. With 40 or more failures, no deliveries could be made.

AN/TPR-36 RELIABILITY ACCEPTANCE CRITERIA



AN/TPQ-37 CONTRACT GOALS/REQUIREMENTS FOR RELIABILITY

The AN/TPQ-37 program began with no formal reliability requirement, although there was a goal of 250 hours MTBF, and a prediction of 209 hours.

Subsequently, in LRIP a reliability improvement program (described later) was adopted, which formally established a requirement for demonstration of a 90-hour MTBF, and a dollar incentive. Reliability requirements were then fixed at 90-hour MTBF, for LRIP and subsequent production units.

AN/TPQ-37 CONTRACT GOALS/REQUIREMENTS FOR RELIABILITY

PROGRAM PHASE	TYPE CONTRACT	MTBF GOAL (HR)	MTBF POINT ESTIMATE	PREDICTION (HR)**
ADVANCED DEVELOPMENT	COST PLUS*	250	-	209
LRIP	COST PLUS	125***	90	
XLRIP	FIXED PRICE		90	
FULL-SCALE PRODUCTION			90	

* WITH COMPETITIVE EVALUATION OF ALTERNATE CONTRACTORS' HARDWARE
** PER MIL HDBK - 217
*** A DOLLAR INCENTIVE WAS PROVIDED TO MEET GOAL

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MAINTAINABILITY REQUIREMENTS (HOURS)

AN/TPQ-36				AN/TPQ-37		
ORGANIZA-TIONAL	DS	GS		ORGANIZA-TIONAL	DS	GS
0.5	2	3.5	MEAN TIME TO REPAIR	0.5	2	3.5
2.0	4	NS	MAX. TIME TO REPAIR	2.0	4	NS
4.0	8	NS	MAX. MAN HRS. TO REPAIR	4.0	8	NS
1.0	4	NS	AVG. MAN HRS. TO REPAIR	NS	NS	NS

(NS = NOT SPECIFIED)

- ALL ORGANIZATION, D.S. AND G.S. REQUIREMENTS WERE TO BE DEMONSTRATED
- MEAN DOWNTIME WAS NOT TO EXCEED 1 HOUR PER DAY
- POWER FOR TEST EQUIPMENT SHOULD BE AVAILABLE AT ANTENNA TRAILER
- ETI SHALL BE PROVIDED FOR DETERMINATION OF REPLACEMENT TIMES
- STOWAGE SPACE WAS TO BE PROVIDED FOR ORGANIZATIONAL SUPPORT
- THERE ARE NO DEPOT REQUIREMENTS FOR MAINTAINABILITY

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MAINTENANCE REQUIREMENTS (CONTINUED)

- FAULT ISOLATION AND REPAIR ON SITE
  - ORGANIZATIONAL - 90% OF REPAIRABLE FAULTS
  - DIRECT SUPPORT - 10% OF REPAIRABLE FAULTS
- AUTOMATIC FAULT ISOLATION (BIT) TO:
  - 1 UNIT FOR 75% OF FAILURES
  - 2 UNITS OR LESS FOR 90% OF FAILURES
  - 8 UNITS OR LESS FOR 98% OF FAILURES
- MINIMUM SPECIAL TOOLS AND TEST EQUIPMENT

MISSION PROFILE ESTABLISHMENT

RADAR MISSION PROFILES

The figure outlines the mission profile for the Weapon Locating Radar as identified in the Materiel Need Documents. The mission length duration is defined along with the number of emplacement/displacement events, as well as scheduled and unscheduled maintenance time allocations per day. Under this mission scenario and the operating environmental conditions, the MTBF requirement is defined as 100 hours for the TPQ-36. The mission reliability requirement for TPQ-37 is 0.74 to 0.85.

MISSION PROFILES - FROM MATERIAL NEED DOCUMENT

MISSION LENGTH	AN/TPQ-36	AN/TPQ-37
● OPERATIONAL TIME	10 DAYS, 24 HR/DAY	24 HOURS
● TRAVEL & MAINTENANCE MODE	21 HRS/DAY	19 HRS/DAY
● EMPLACEMENT/ DISPLACEMENTS	3 HRS/DAY	5 HRS/DAY
● SCHEDULED & UNSCHEDULED MAINTENANCE TIME	1 HR/DAY	3/4 HR/DAY
OPERATING ENVIRONMENTAL CONDITION		
● RAIN PERFORMANCE	2 MM/HR	4 MM/HR
● ENVIRONMENT PER AR70-38	WORLDWIDE	WORLDWIDE

RELIABILITY AND MAINTAINABILITY DEFINITIONS

FIREFINDER RELIABILITY FAILURE DEFINITION

The FIREFINDER reliability failure definition is a part of the AN/TPQ-36 and AN/TPQ-37 production contracts. This failure definition is designed to measure the radar mission reliability. It discounts failures of redundant hardware, and failures of hardware and software which do not significantly degrade performance of the mission. This failure definition is used for scoring contractor reliability acceptance tests, and for measuring progress in the contractors' reliability growth program. The same failure definition is used in scoring reliability achieved in the government's development and operational (DT/OT) testing and in assessment of reliability experienced with field radars. The use of a common failure definition provides a continuity and clarity to the assessment of reliability throughout the program. This can improve communication among the user, developer and contractor, and result in an effective reliability program.

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FIREFINDER RELIABILITY FAILURE DEFINITIONS

- USED TO COMPUTE MTBF OF CONTRACTOR FURNISHED EQUIPMENT (CFE)
- DEFINITIONS ARE IN THE CONTRACT
- RELIABILITY FAILURE DEFINITIONS COMMON TO BOTH CONTRACTOR AND FIELDED RADARS
- ALL FAILURES ARE CATEGORIZED AS EITHER RELEVANT OR NON-RELEVANT

- RELEVANT FAILURE (CHARGEABLE)
  - REDUCES SYSTEM PERFORMANCE BELOW SPECIFIED LEVELS
  - CAUSED BY DESIGN OR MANUFACTURING DEFECTS OR PHYSICAL DETERIORATION

- NON-RELEVANT FAILURE (NON-CHARGEABLE)
  - DAMAGE FROM IMPROPER INSTALLATION, MISHANDLING, OR ABUSE
  - FAILURE DUE TO ERROR IN TEST PROCEDURES
  - FAILURE DUE TO OVERSTRESS
  - OPERATOR ERRORS
  - SECONDARY FAILURES
  - FAILURE OF GFE ITEMS
  - REDUNDANT ITEMS

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INCENTIVES

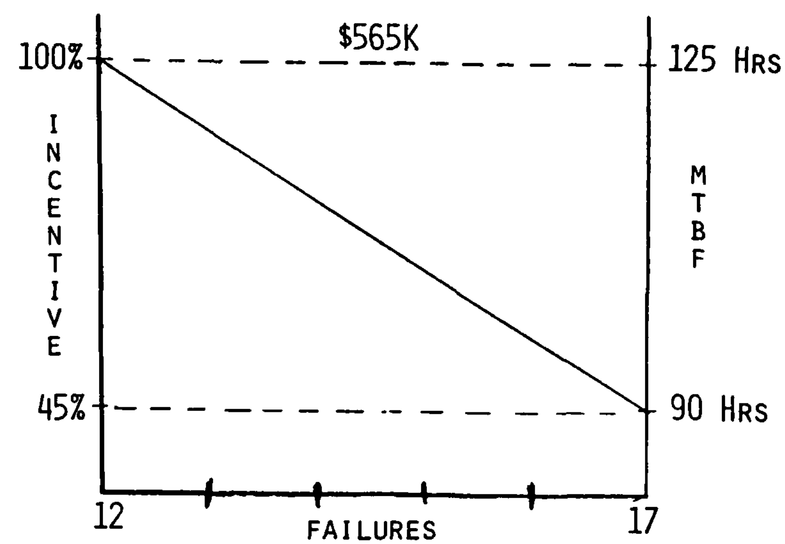
AN/TPQ-37 LRIP RELIABILITY INCENTIVE

The reliability incentive was an integral portion of the LRIP reliability improvement program (RIP). While the RIP provided program elements which the contractor and government agreed were necessary to achieve reliability, the incentive established a reliability requirement and a meaningful goal.

The reliability requirement was in the form of a guaranteed MTBF of 90 hours; 17 or fewer failures during a 1500-hour reliability acceptance test on a sample of two radar systems. The reliability goal was in the form of a cash incentive, which provided increasing dollar amounts for demonstration MTBF greater than 90-hours, with a maximum award paid for demonstration of a 125 MTBF, 12 or less failures during the 1500-hour reliability acceptance test.

INCENTIVES IN THE CONTRACTS

PROGRAM	RELIABILITY IMPROVEMENT PROGRAM (RIP)	VALUE OF INCENTIVE	RESULT
AN/TPQ-37	RIP CREATED AN INCENTIVE IN DOLLARS FOR SUCCESSFUL RESULTS OF A GOVERNMENT FUNDED PROGRAM. THE CONTRACTOR WAS REQUIRED TO MEET A 90-HR MTBF IN DEMONSTRATION.	$5.5 MILLION, LESS THE COST OF THE RIP. THE OBJECT WAS TO ACHIEVE 12 OR LESS FAILURES IN 1500 HOURS OF TESTING	THE COST OF THE RIP WAS $4.8 MILLION. CONTRACTOR EARNED 90% OF THE INCENTIVE, $508K
AN/TPQ-36	THERE WERE NO RELIABILITY RELATED INCENTIVES EXCEPT AS CONTAINED IN THE DESIGN-TO-COST (DTC) PROGRAM DESCRIBED ON PAGE 188		



STRUCTURE OF THE INCENTIVE FOR AN/TPQ-37 RELIABILITY IMPROVEMENT PROGRAM

FAILURES IN 1500 HOURS	$ INCENTIVE	ACTUAL
12 OR LESS	565K	
13	508K	X
14	452K	
15	396K	
16	339K	
17	283K	

SOURCE SELECTION CRITERIA

SOURCE SELECTION CRITERIA

<u>TPQ-36</u>

RFP STATED R&M REQUIREMENTS

COMPETING VENDORS EACH MADE PROPOSALS TO ARMY TO MEET R&M REQUIREMENTS

EACH OF FOUR RESPONDING VENDORS PROPOSED TO MEET 100 HOUR MTBF

SELECTION BASED ON "COST REALISM"

<u>TPQ-37</u>

RFP FOR ADVANCED DEVELOPMENT DID NOT STATE R&M REQUIREMENTS

THERE WERE TWO COMPETITIVE CONTRACTORS IN ADVANCED DEVELOPMENT

EACH CONTRACTOR BUILT A DEMONSTRATION MODEL

GOVERNMENT PERFORMED A TEST ON EACH MODEL TO DEMONSTRATE PERFORMANCE (PRIMARY), RELIABILITY AND MAINTAINABILITY (SECONDARY)

SOURCE SELECTION WAS BASED PRIMARILY ON TECHNICAL CAPABILITY WITH MINOR CONSIDERATION OF RELIABILITY AND MAINTAINABILITY

PLANNING/CONTROL AND EMPHASIS

AN/TPQ-36

PLANNING CONTROL AND EMPHASIS

- THE ORIGINAL CONTRACT HAD A RELIABILITY REQUIREMENT OF 100-HR MTBF MINIMUM
- THE CONTRACT PROVIDES FOR DEMONSTRATED GROWTH OF RELIABILITY REQUIREMENT TO 200-HR MTBF IN LOTS 5 THROUGH 7
- THE PROGRAM INCLUDED:
  - VENDOR ITEM CONDITIONING
  - SYSTEMS DEVOTED TO RELIABILITY GROWTH
  - FAILURE ANALYSIS
  - PARTS SCREENING

AN/TPQ-37

PLANNING CONTROL AND EMPHASIS

- THE ADVANCED DEVELOPMENT CONTRACT HAD NO RELIABILITY REQUIREMENT
- RELIABILITY IMPROVEMENT PROGRAM (RIP)(1977) IN THE LRIP CONTRACT CREATED A REQUIREMENT AND CAUSED CONTRACTOR TO DEVELOP A PROGRAM TO ACHIEVE THE REQUIREMENTS
- THE PROGRAM WAS COMPREHENSIVE, AND WAS FOLLOWED AS EVIDENCED BY SUCCESSFUL COMPLETION OF RELIABILITY DEMONSTRATION TEST
- DESIGN ANALYSIS, DESIGN CHANGES AND SCREENING AT SEVERAL LEVELS WAS ACCOMPLISHED BY THE RIP. FOR EXAMPLE:

    1. PROGRAM REVIEWS
    2. RELIABILITY GROWTH REPORTS (FIND AND FIX)
    3. RELIABILITY DESIGN CHANGES
    4. VENDOR ITEM CONDITIONING (TYPICALLY TEMPERATURE CYCLING)

<u>IN COMMON -- AN/TPQ-36 AND AN/TPQ-37</u>

- HIGH LEVEL FAILURE REVIEW BOARD OVERSEES RESOLUTION OF ALL FAILURES
- TOP MANAGEMENT ENFORCED EMPHASIS (IN 1982) TO ASSURE THAT KEY PROBLEMS WERE RESOLVED

MONITOR/CONTROL OF SUBCONTRACTORS AND SUPPLIERS

FIREFINDER--CONTROL OF SUBCONTRACTORS AND SUPPLIERS

Reliability and maintainability requirements of the prime contract were evaluated and allocated to the subcontractor via the procurement specification.

During the development effort, the prime contractor conducted design reviews and performed thermal studies and R&M analyses prior to conducting qualification testing.

Stress screens were developed as one of the corrective actions as a result of development test failures. These requirements were incorporated into the procurement specifications.

A failure feedback and corrective action system was imposed on the complex/critical item suppliers.

Production control (lot qualification tests) testing was continuously monitored by product assurance on the production programs to assure that any failures attributed to subcontractor items were reviewed by the Project Failure Review Board (PFRB).

Product assurance engineering provided an active participant as co-chairman to the PFRB and ensured that failure analysis and corrective action was initiated, as required, on the identified subcontractor failed items.

MONITOR AND CONTROL OF SUBCONTRACTORS/SUPPLIERS

- FIRST ARTICLE TESTS AT SUBCONTRACTOR
- SELECTED ITEMS RECEIVED ENVIRONMENTAL TEST
- DURING DEVELOPMENT, VENDOR FAILURES WERE ANALYZED, CORRECTIVE ACTIONS TAKEN
- STRESS SCREENS WERE DEVELOPED ON SELECTED ITEMS
- A FEEDBACK AND CORRECTIVE ACTION SYSTEM WAS DEVISED FOR CRITICAL ITEM SUPPLIERS

56/2-5

DEVELOPMENT OF DESIGN REQUIREMENTS

AN/TPQ-36 RAM
AUDIT TRAIL FROM MATERIEL NEED TO REQUIREMENTS/TEST

PERFORMANCE REQUIREMENT	MATERIEL NEED	REQUIREMENT AND TEST MIL-R-49195 (SYSTEM SPEC)
RADAR DETECTION	CLASSIFIED PERFORMANCE CAPABILITY	LIVE FIRE FIELD TEST
RELIABILITY	100-HOUR MTBF MIN 400-HOUR GOAL	MIL-STD-781 DEMONSTRATED: (θ_0) 150-HOUR MTBF; (θ_1 = 100) LOTS 1 TO 4 (θ_0) 200-HOUR MTBF; (θ_1 = 100) LOTS 5 TO 7
AVAILABILITY/ MAINTAINABILITY	10-DAY (24-HOUR DAY) OPERATION WITH 1 HR/ DAY SCHEDULED AND UN-SCHEDULED MAINTENANCE	MAINTAINABILITY DEMONSTRATION: ORG LEVEL (30-MIN MTTR; 120-MIN MAX TIME TO REPAIR)(FOR 90% MAINTENANCE ACTIONS) DS LEVEL (2-HR MTTR)
ENVIRONMENTAL CONDITIONS	SYSTEM TO OPERATE IN: HOT-DRY; WARM-WET; COLD AND INTERMEDIATE CONDITIONS AR 70-38	OPERATING ENVIRONMENTAL TESTING UNDER CONDITIONS: • HIGH AND LOW TEMP • ALTITUDE • RAIN • DUST • SALT ATMOSPHERE (TEST ITEMS) • FUNGUS (TEST ITEMS) • WATER FORDING • MUNSON ROAD (TOTAL SYSTEM) • RAIL HUMP • VIBRATION AND SHOCK
STORAGE CONDITIONS	CONDITIONS OF STORAGE: TEMP; HUMIDITY; ALTI-TUDE; ONE-YR MIN, FIVE-YR GOAL	NON-OPERATIONAL ENVIRONMENTAL TESTING UNDER CONDITIONS: • HIGH AND LOW TEMP • ALTITUDE • RAIN • HUMIDITY (SOAK) • DUST • FUNGUS • SALT ATMOSPHERE

56/2-6

AN/TPQ-37 RAM
AUDIT TRAIL FROM MATERIEL NEED TO REQUIREMENTS/TEST

PERFORMANCE REQUIREMENT	MATERIEL NEED	REQUIREMENT AND TEST MIL-R-49360 (SYSTEM SPEC)
RADAR DETECTION	CLASSIFIED PERFORMANCE CAPABILITY	LIVE FIRE FIELD TEST PER MIL R49360 TO DEMONSTRATE PROC, CEP
RELIABILITY	90-HR MTBF MIN POINT ESTIMATE 180-HR GOAL	FORMAL DEMONSTRATION 90-HR MTBF MIN POINT ESTIMATE
AVAILABILITY/ MAINTAINABILITY	MISSION DURATION: 24 HR, OF WHICH 19 HR IS IN OPERATIONAL MODE; 5 HR IN TRAVEL AND MAINTENANCE MODE	MAINTAINABILITY DEMONSTRATION PER MIL STD 471, ORG LEVEL (30-MIN MTTR; 120 MIN MAX TIME TO REPAIR) DS LEVEL (2-HR MTTR)
ENVIRONMENTAL CONDITIONS	SYSTEM TO OPERATE IN CATEGORIES 1-7, AR 70-38	OPERATING ENVIRONMENTAL TESTING PER MIL STD 810C, AND AR 70-38: HIGH AND LOW TEMP, ALTITUDE, RAIN, DUST, SALT ATMOSPHERE (TEST ITEMS), FUNGUS (TEST ITEMS), WATER FORDING, MUNSON ROAD (TOTAL SYSTEM), RAIL HUMP, VIBRATION AND SHOCK
STORAGE	CONDITIONS OF STORAGE: HIGH TEMPERATURE, LOW TEMPERATURE, AND EXTREME LOW TEMPERATURE	NON-OPERATIONAL ENVIRONMENTAL TESTING UNDER CONDITIONS: HIGH AND LOW TEMP, ALTITUDE, RAIN, HUMIDITY (SOAK), DUST, FUNGUS, SALT ATMOSPHERE

56/2-7

WIND LOADING REQUIREMENTS

NON-OPERATING	TPQ-36	TPQ-37
CONSTANT	65 MPH	80 MPH
GUSTS	100 MPH	118 MPH
OPERATING		
CONSTANT	52 MPH	40 MPH
GUSTS	75 MPH	75 MPH

NON-OPERATING CONDITIONS: TRANSPORT CONFIGURATION

- ANTENNA DOWN
- ON WHEELS - OFF JACKS

56/1-36

DESIGN ALTERNATIVE STUDIES

R&M DESIGN IMPROVEMENTS

During the course of the AN/TPQ-36 and AN/TPQ-37 programs, many studies were conducted with the objective of reducing cost, improving performance, and improving reliability and maintainability (RAM). The charts illustrate some of the major issues which were faced, and the area of benefit as a result of the design improvement.

As one example, there were initially separate shelter designs for each radar. The adoption of a common shelter led to obvious economies in manufacturing, and substantial savings in logistics costs to support the radars. The accommodation of both radars was made with a very nominal increment in factory cost/radar.

AN/TPQ-36
RELIABILITY AND MAINTAINABILITY DESIGN IMPROVEMENTS

ITEM	ISSUES/RESOLUTION
• COMMON SHELTER FOR TPQ-36 AND TPQ-37 RADARS	SAVING IN LOGISTICS (SPARING AND TRAINING) WITH SMALL ADDITIONAL COST TO INDIVIDUAL RADARS
• TWT BEAM SCRAPER	ELIMINATE CROWBAR CIRCUIT UPGRADING RELIABILITY AND MAINTAINABILITY
• REPLACE TDA RF PREAMPLIFIER WITH GaASFET	IMPROVED RADAR RANGE RESULTING FROM A LOWER NOISE FIGURE
• TRANSMITTER HVPS REPLACED TRANSISTOR WITH SCR INVERTER REGULATOR	RELIABILITY IMPROVEMENT
• COMMON TILT SENSOR/AZIMUTH ENCODER	REDUCED LOGISTICS COST
• CIRCUIT CARDS REDESIGNED TO 80 OR 100 PIN CONNECTOR AND ALL DIPS	IMPROVEMENT IN R&M WITH SIGNIFICANT UPGRADE IN TOTAL LOGISTICS AND PRODUCTION COST REDUCTION
• EMBEDDED COMPUTER USING STANDARD FIREFINDER CIRCUIT CARD DESIGNS	LARGE INCREASE IN ENVIRONMENTAL CAPABILITY, R&M; PRODUCTION COST SAVINGS; PROVIDED COMPUTER EXPANSION CAPABILITY
• LINE PRINTER CHANGED FROM AN IMPACT TO AN ELECTROSTATIC TYPE	ELIMINATED PRIOR HUMIDITY PAPER PROBLEM, UPGRADE IN RELIABILITY PERFORMANCE

56/2-8

AN/TPQ-37 RELIABILITY MODIFICATIONS

- REPLACING PARAMPS WITH GAS FET TRANSISTOR AMPLIFIERS IN RECEIVER/EXCITER
- USE THE AN/TPQ-36 A/D CONVERTER IN THE SIGNAL PROCESSOR
- SIMPLIFY THE CLUTTER MAP AND TARGET DETECTION AS IN AN/TPQ-36
- DELETE THE UNNEEDED 28V POWER SUPPLY IN THE TRANSMITTER
- IMPROVE THE TRAILER LEVELING JACKS
- EMPLOY THE AN/TPQ-36 OSCILLATOR UNITS
- IMPROVE COMPUTER RACK COOLING IN THE SHELTER
- ENCLOSE THE CABLES (UNDER THE WLU)
- TRANSMITTER DRIVER AMPLIFIER CHANGED TO A SOLID STATE DEVICE
- ADDED MODULATING ANODE TO TRANSMITTER TUBE
- ANTENNA MODULE REDESIGN TO THREE SIGNIFICANT PARTS

AN/TPQ-37 MAINTAINABILITY MODIFICATIONS

MAINTAINABILITY ILS MODIFICATIONS

- EXPANSION OF BITE SOFTWARE
- IMPROVE TRANSMITTER FAULT PROCESSOR
- IMPROVE ANTENNA TEST TARGET INJECTION AND DISTRIBUTION
- RELOCATE POWER SUPPLIES FOR BEAM STEERING
- IMPROVE ACCESSIBILITY TO POWER SUPPLIES IN TRAILER
- ADD SHELTER-TO-TRAILER TELEPHONE
- INSTALL SPARES STOWAGE IN TRAILER
- ANTENNA BEAM STEERING REDESIGN FOR COMMON CIRCUIT CARD AND PACKAGING
- REPLACED ANTENNA AZIMUTH ENCODER WITH AN/TPQ-36 UNIT
- BORESIGHT TELESCOPE COMMON TO BOTH FIREFINDER RADARS

56/2-10

Design-to-unit-production-cost was one of the principal design objectives of the AN/TPQ-36 radar. A $700,000 award was made for this purpose. The objective was achieved by rigorous examination of all production costs while simultaneously ensuring that the performance and R&M requirements would be met. These examinations were done not only at the hardware design and implementation level, but at earliest stages of conceptual design. An example of one decision resulting from these examinations is shown in the chart.

The decision to employ a phase-frequency scan antenna and sequential lobing in both planes (as opposed to a phase-phase scanning antenna with monopulse tracking) had obvious cost reduction benefits. However, this decision could be made only with the assurance achieved by thorough analysis and computer simulation of expected performance. It was necessary for the U.S. Army program office to take some risk in order to achieve its goal.

The payoff of the optimum antenna design would be of great significance: cost would be reduced and RAM improved. The factors that made this trade-off a success were: (a) An incentive fee award for meeting the cost goal, (b) The U.S. Army project management and the contractor operated cooperatively, not as adversaries, toward a mutually beneficial goal. For example, it was very important for the U.S. Army to understand the risks involved in the antenna decision. The contractor had to be completely open in imparting this information.

DTUPC - SAMPLE SUMMARY OF MAJOR TRADE STUDY FOR AN/TPQ-36

<u>PROBLEM</u>	• USE OF PHASE-FREQUENCY SCAN ANTENNA WITH SEQUENTIAL LOBING INSTEAD OF PHASE-PHASE SCANNING WITH MONOPULSE TRACKING
<u>MEANS OF RESOLUTION</u>	• COMPUTER SIMULATION OF PERFORMANCE • WILLINGNESS OF GOVERNMENT TO ACCEPT SOME RISK TO ACHIEVE GOAL • EVALUATION OF COST, RAM OF ALTERNATE DESIGNS
<u>INCENTIVES</u>	AN INCENTIVE FEE WAS AVAILABLE AND AWARDED FOR MEETING DTUPC COAL
<u>SOLUTION</u>	THE PHASE-FREQUENCY ANTENNA CONCEPT WAS SELECTED, BECAUSE • ANTENNA COST WAS REDUCED • THE NUMBER OF PARTS WAS REDUCED, AS WELL AS DESIGN COMPLEXITY • RELIABILITY WAS IMPROVED, AS WAS MAINTAINABILITY • SEQUENTIAL LOBING ALLOWED OPERATION WITH A SINGLE RECEIVER

PARTS AND MATERIAL SELECTION AND CONTROL

ACHIEVEMENT OF RELIABILITY REQUIREMENTS BY PARTS SELECTION/CONTROL

A producibility/standardization guide was created at the beginning of the radar design phase. This plan contained guidelines for parts selection and specified allowable stress levels for all major component classes.

Allocations were made for reliability. Preferred parts and materials lists were also provided. Detailed standards were published for printed wiring boards.

Much of the success of Firefinder reliability design effort was due to the up-front planning of consistent and standardized requirements clearly disseminated to the designer.

ACHIEVEMENT OF R&M REQUIREMENTS BY PARTS SELECTION/CONTROL

- A STANDARDIZATION/PRODUCIBILITY MANUAL WAS CREATED FOR EACH RADAR
- RELIABILITY ALLOCATIONS WERE ACCOMPLISHED
- DERATING GUIDELINES AND RULES WERE ESTABLISHED
- PREFERRED PARTS AND MATERIAL LISTS WERE ESTABLISHED

TWO APPROACHES TO PARTS CONTROL

TPQ-36 ANTENNA

- CUSTOMER IMPOSED STRICT PARTS CONTROL PLUS NONSTANDARD PARTS REVIEW AND APPROVAL BY DESC
- NO PARTS UPGRADE REQUIRED
- RESULT: 2.30 RATIO OF MIL STANDARD/NONSTANDARD PART TYPES

TPQ-37 ANTENNA

- DESIGNED WITH INDUSTRIAL STANDARD AND GSG STANDARD PARTS
- NO NONSTANDARD PARTS SUBMITTAL REQUIRED
- PARTS UPGRADED IN LRIP
- RESULT: 1.84 RATIO OF MIL STANDARD/NONSTANDARD PART TYPES

TPQ-36/37 SHELTER

- DEVELOPED UNDER TPQ-37 GROUND RULES, BUT INFLUENCED BY THE TPQ-36 REQUIREMENTS
- RESULT: 1.98 RATIO OF MIL STANDARD/NONSTANDARD PART TYPES

56/2-12

ECP-5 RELIABILITY/MAINTAINABILITY PARTS UPGRADE FOR TPQ-37 ANTENNA AND SHELTER

46 SEMICONDUCTORS UPGRADED TO MEET MILITARY TEMPERATURE RANGE REQUIREMENTS

47 COMPONENT SPECS UPGRADED TO REQUIRE BURN-IN PRIOR TO ACCEPTANCE TESTING

63 PARTS SELECTED FOR ALTERNATE SOURCE DEVELOPMENT

DERATING CRITERIA

DERATING FOR AN/TPQ-36 AND AN/TPQ-37

Derating was required for all major electronic and mechanical components in order to meet R&M requirements.

The producibility/standardization manual, created at the program outset, provided in-depth criteria and guidelines for derating along with application guidelines. In conjunction with these guidelines, the derating criteria resulted in low average stress, thus providing more inherently reliable equipment.

Over many years of field testing, field operations and engineering tests, very few cases of over-stress were uncovered (<.1%). Changes were accomplished early, with little impact on the program.

56/1-46

DERATING OF COMPONENTS
AN/TPQ-36 AND AN/TPQ-37

- REQUIRED BY RELIABILITY PROGRAM PLAN
- PUBLISHED IN DESIGN GUIDES AT START OF DESIGN
- COMPONENT TYPES COVERED
  - INTEGRATED CIRCUITS
  - TRANSISTORS
  - DIODES
  - CAPACITORS
  - MAGNETICS
  - RESISTORS
  - CONNECTORS
  - SWITCHES
  - RELAYS
  - GEARS AND BEARINGS

56/2-14

THERMAL AND PACKAGING CRITERIA

THERMAL-PACKAGING CRITERIA

Thermal design guidelines were established by the environmental limits required by the system performance specification. In addition to the ambient temperature limits, the system was required to operate with a solar heat load typical of the desert environment. Thermal analyses were performed to determine temperature rise in the various enclosures as a function of air flow rate. Blowers were found to be required in order to have sufficient heat removal to minimize temperature rise. In regions of high power concentration, such as power supplies, air was ducted through cold plates on which the power supplies were mounted.

In the case of the AN/TPQ-37 transmitter, a liquid cooling system is required to meet the vendor's specifications.

Temperature tests were performed on some components and on complete systems.

AN/TPQ-37
THERMAL DESIGN CONDITIONS

	POWER DISSIPATION WATTS	ALLOWABLE COMPONENTS TEMPERATURE (°F)
ANTENNA ARRAY		
PHASE SHIFTERS	1794	220 (104°C)
RF LOAD RESISTORS	93	220 (104°C)
SUBARRAY MODULE (LINES)	565	220 (104°C)
1:6 POWER DIVIDERS	214	220 (104°C)
DRIVER LOAD RESISTORS	252	220 (104°C)
TOTAL	2918	
BSU		
POWER SUPPLIES	1918	176 (80°C)
DRIVER CARDS	768	176 (80°C)
LOGIC CARDS	252	176 (80°C)
TOTAL	2938	

NOTE: INTENDED UPPER LIMIT TEMPERATURE, WITH 125°F INLET AIR. THESE LIMITS WERE EXPERIMENTALLY VERIFIED

56/2-15

TESTABILITY ANALYSIS

TESTABILITY ANALYSIS

Built-in-test (BIT) was required in the system performance specification. Therefore, BIT design was accomplished concurrently with the radar system design. Test point selection and design was considered in system layout and packaging. A simulation of the signal processor group was accomplished in order to achieve insight into the implementation of BIT.

Testing, both on-line and off-line, is generally accomplished by injecting computer controlled test signals at the input to the radar and monitoring the progress of the test signal through the radar system using computer controlled diagnostics. Outputs of unique sensors are also reported to the radar computer for analysis. The computer commands a message to be printed out for the operator if a fault exists, and identifies which unit requires replacement.

TESTABILITY ANALYSIS, TPQ-36 AND TPQ-37

- BIT WAS REQUIRED BY CONTRACT
- BIT DESIGN WAS ACCOMPLISHED CONCURRENT WITH RADAR DESIGN
- TEST POINT SELECTION WAS MADE IN SYSTEM LAYOUT
- COMPUTER SIMULATION OF THE SIGNAL PROCESSOR WAS MADE TO ESTABLISH OPTIMUM IMPLEMENTATION OF BIT
- BASIS FOR TEST POINT SELECTION WAS ENGINEERING JUDGMENT
- BIT GIVES FAULT DETECTION INFORMATION TO IDENTIFY WHERE FAULTS ARE. THE OPERATOR THEN USES OFF-LINE BIT WHICH FURTHER LOCALIZES FAILURE TO ONE OF SEVERAL LRUs. ALSO, MANY CARDS HAVE LEDs WHICH MAY BE LIT TO POINT OUT BAD CARDS
- THE MAINTAINABILITY DEMONSTRATION PROVED THE ABILITY OF THE BIT TO FIND 100 RANDOMLY SELECTED SIMULATED FAULTS

AN/TPQ-36 AND AN/TPQ-37 EQUATE

The Equate (AN/USM-410) was the U.S. Army choice for test/repair of Firefinder assemblies. A trade-off study was done to determine the most cost effective means for test of Firefinder assemblies. A total of 106 CCA types are tested at general support level on Equate using only two interface devices (adapters). This was accomplished because of the standardization of design for CCAs throughout the radars and the designing of interface devices with all CCAs being considered. Twenty-nine assemblies are tested at the depot level using eight interface devices. Seventy-eight assemblies are tested using commercial test equipment and bench test fixture. These items were electro/mechanical or simpler power supplies which did not warrant automatic test procedures because of complexity or anticipated throughput. Ten high-voltage assemblies are tested on special test equipment designed to provide sufficient power and operator protection.

AN/TPQ-36 AND AN/TPQ-37 EQUATE

EQUIVALENT QUALITY ASSURANCE AUTOMATIC TEST EQUIPMENT

- US. ARMY EQUIPMENT (AN/USM-410)
- TRADE-OFF STUDY
- GENERAL SUPPORT LEVEL
  - 106 CCA TYPES
  - 2 INTERFACE DEVICES (ADAPTERS)
- DEPOT LEVEL
  - 29 ASSEMBLIES PLUS 106 CCA TYPES TESTED
  - 8 INTERFACE DEVICES (ADAPTERS)
- ACCOMPLISHED BY DESIGN STANDARDIZATION

56/1-36

BIT AND ATE PERFORMANCE

BIT PERFORMANCE

- BIT WAS DESIGNED TO PROVIDE A COMPREHENSIVE MEANS OF TESTING THE SYSTEM
- BIT DESIGN FEATURES

  (A) ON-LINE BIT USES CONTINUOUS TESTS TO ESTABLISH THE PRESENCE OF A SYSTEM FAULT

  (B) OFF-LINE BIT IS USED TO FAULT ISOLATE TO ONE OR SEVERAL LRUs

- THE PROCEDURE USED BY THE CONTRACTOR WAS

  (1) BIT AND LRU DESIGN WERE CONCURRENT

  (2) OFF-LINE BIT WAS DESIGNED FIRST, THEN ON-LINE BIT

  (3) EVERY TEST POINT WAS MANUALLY TESTED TO VERIFY THAT INJECTED FAULTS COULD BE DETECTED. THIS WAS THE BEST WAY TO GET THE MOST CERTAINTY IN KNOWING THE EFFECTIVITY OF THE BIT

  (4) FAULTS WERE INITIALLY DECLARED ON THE BASIS OF A FAULT IN A SINGLE TEST (ONE OUT OF ONE, TESTED HUNDREDS OF TIMES PER SECOND); LATER, CONTRACTOR SELECTIVELY CHANGED THE CRITERIA TO 2 OUT OF 2, 2 OUT OF 3, M OUT OF N, AS APPROPRIATE TO REDUCE FALSE FAULT INDICATIONS

  (5) IT WAS FOUND THAT THE BIT, AS DESIGNED, WAS ABLE TO DETECT MOST OF THE ACTUAL FAULTS THAT HAVE OCCURRED TO DATE

  (6) PROCEDURES WERE IMPLEMENTED TO ENSURE THAT A "FAULT" IS REAL PRIOR TO PERMANENT CARD REMOVAL

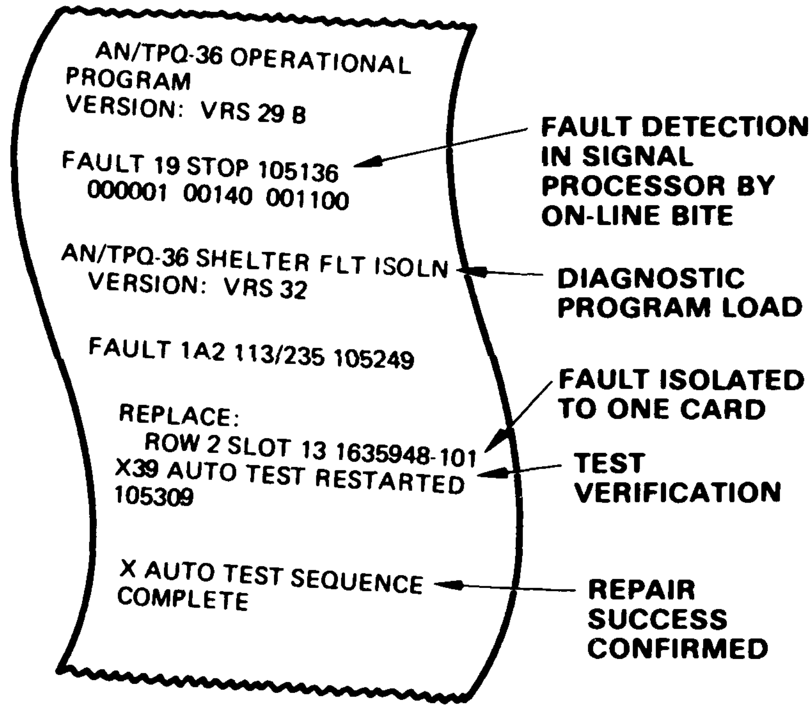
56/2-17

AUTOMATED BUILT-IN TEST EQUIPMENT SIMPLIFIES MAINTENANCE

KEY MAINTAINABILITY FEATURES

- **AUTOMATIC ON-LINE FAULT DETECTION**
- **AUTOMATIC OFF-LINE FAULT ISOLATION AND REPAIR CONFIRMATION**
- **MINIMUM EASILY-MADE MANUAL TESTS**
- **MOST MAINTENANCE ACTIONS PERFORMED BY CREW MEMBERS**

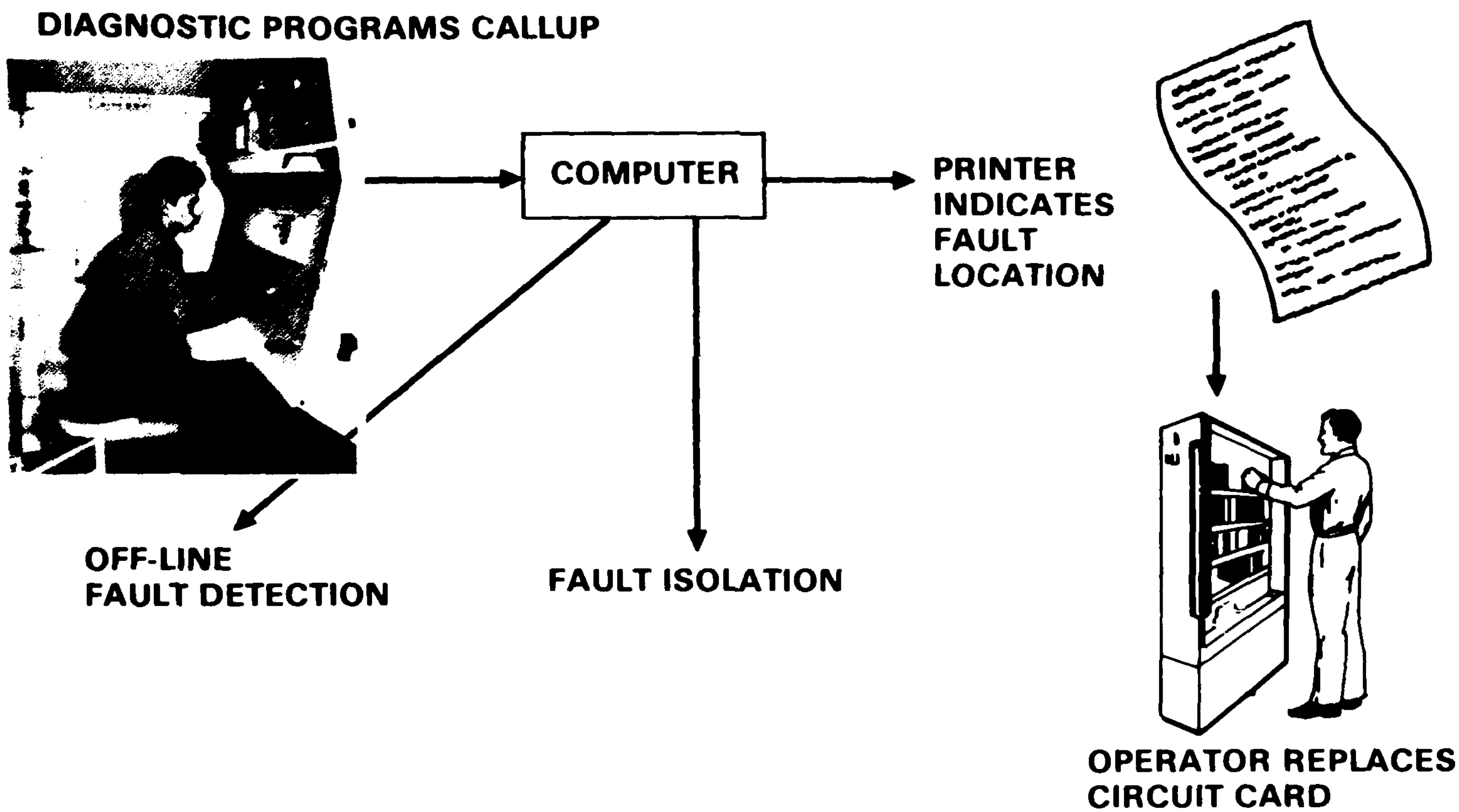
EXAMPLE OF STEP-BY-STEP MAINTENANCE ON TAPE



HARDWARE AND SOFTWARE ALLOCATIONS FOR BIT

<u>OPERATIONAL</u>		
CIRCUITRY	5.0%	ALL DIGITAL/ANALOG CIRCUITRY
SOFTWARE	4.4%	
MEMORY ALLOCATED	3.7%	
<u>OFFLINE</u>		
SOFTWARE	100%	

OFF-LINE BIT PROVIDES A HIGH LEVEL OF CONFIDENCE THAT THE FAULT CAN BE EASILY LOCATED AND CORRECTED



AUTOMATED BIT SIMPLIFIES MAINTENANCE

Mean time to repair is rated at 30 minutes. More than 90% of all repairs can be made in the field, often in less than ten minutes.

The key maintainability features are:

1. On-line computer-aided system status testing for rapid fault detection, and
2. Off-line software for fault isolation.

To this end, built-in-test (BIT) circuitry is incorporated throughout the radars. System status is periodically monitored with automatic test signals many times per second. When a failure is detected during these system status tests the operator is alerted by an alarm, by a written message on the printer and on the B-scope display.

Identification of the failed unit is accomplished by a special fault isolation computer program on the system tape cassette. Using this, the crew member can normally isolate the *problem to a single LRU.*

The printout in the chart illustrates the typical steps performed by a crew member in isolating a signal processor fault. The fault is first detected by on-line automatic monitoring and then isolated by off-line testing. The failed LRU is replaced with a spare one, and the system returns to operation.

The reduction of maintenance actions to computer-aided fault isolation means that the operations crew is prepared to perform maintenance after a minimal amount of training. This minimizes the number of personnel required to support the system in the field.

AUTOMATED BUILT-IN TEST EQUIPMENT
SIMPLIFIES MAINTENANCE

- AUTOMATIC ON-LINE FAULT DETECTION
- AUTOMATIC OFF-LINE FAULT ISOLATION AND REPAIR CONFIRMATION
- MINIMUM EASILY-MADE MANUAL TESTS
- MOST MAINTENANCE ACTIONS PERFORMED BY CREW MEMBERS

56/1-40

BIT DEVELOPMENT COSTS ($M)

	AN/TPQ-36	AN/TPQ-37	TOTAL
SOFTWARE	1.1	2.8	3.9
HARDWARE	.4	.9	1.3
TOTAL	1.5	3.7	5.2

56/1-41

FEATURES TO FACILITATE MAINTENANCE

MAINTENANCE GOALS/ACHIEVEMENT

Maintainability was enhanced initially by the imposition of requirements in the contract. This caused detailed reviews to be made of the concepts of design which would meet the requirements.

The key feature to assure the required maintainability was the incorporation of the on-line and off-line BIT. Second, the use of a minimum of special tools and test equipment at the organizational level was accomplished. Also, provision was made for carrying one of each card (or LRU) type as organization spares. Other LRU types are provided in direct support spares, one set per division.

FEATURES TO FACILITATE MAINTENANCE

- USE OF ON-LINE FAULT DETECTION AND OFF-LINE FAULT ISOLATION
- BUILT-IN-TEST (BIT) HARDWARE AND SOFTWARE
- FAULT DETECTION AND ISOLATION IS 90% AUTOMATIC BIT
- ORGANIZATIONAL LEVEL SPARES ARE STORED IN EQUIPMENT TO FACILITATE QUICK MAINTENANCE
- STANDARD TEST EQUIPMENT TO SUPPORT BIT AT ORGANIZATIONAL AND DIRECT SUPPORT LEVELS

FEATURES TO FACILITATE SUPPLY SUPPORT

- ONE EACH OF EVERY CARD TYPE REPLACED AT ORGANIZATIONAL LEVEL IS STORED IN THE SHELTER
- REMAINING REPLACEABLE ASSEMBLIES CARRIED BY DIRECT SUPPORT IN MAINTENANCE VEHICLE. ONE SET PER DIVISION

56/2-18

U.S. ARMY MAINTENANCE CONCEPT

- OPERATOR - FAULT DETECTION AND SYSTEM STATUS
- ORGANIZATIONAL - FAULT ISOLATION AND REPAIR BY REPLACEMENT OF FAILED LRUs
- DIRECT SUPPORT - FAULT ISOLATION, ADJUSTMENTS AND ALIGNMENTS AND REPLACEMENT OF FAILED UNITS
- GENERAL SUPPORT - AUTOMATIC TEST EQUIPMENT (ATE) USED TO REPAIR DIGITAL AND HYBRID CARDS REPLACED BY ORG AND DS LEVELS
- DEPOT - REPAIR HYBRID AND ANALOG CARDS USING ATE REPAIR UNITS/ASSEMBLIES USING SPECIAL AND COMMERCIAL TEST EQUIPMENT. OVERHAUL/ REFURBISHMENT OF RADAR SYSTEMS

56/2-19

LOGISTIC SUPPORT ANALYSIS RECORD

- DATA BASE FOR TECHNICAL MANUALS AND TRAINING
- MAINTENANCE TASKS ANALYSIS
- MAINTENANCE ALLOCATION CHART
- MAINTENANCE PROCEDURES
- SUMMARIES OF MAINTENANCE TASKS AND REQUIREMENTS
- SELECTION OF REQUIRED TOOLS AND TEST EQUIPMENT
- SPARES RECOMMENDATIONS

ENVIRONMENTAL STRESS SCREENING OF PARTS

ENVIRONMENTAL STRESS SCREENING

Environmental Stress Screening (ESS) for selected complex vendor items is required in AN/TPQ-36 and AN/TPQ-37 production contracts. Early failures in field testing caused implementation of additional ESS of system, equipment, LRUs and parts. The concept used was to impose ESS on the lowest reasonable level of equipment or parts.

The concept of using failure analysis and corrective action was also used to help obtain the goal of minimizing the need for the screen.

Improvements in procurement specs along with ESS and failure feed-back have contributed to improved reliability.

ENVIRONMENTAL STRESS SCREENING OF PARTS/EQUIPMENT

PARTS

HIGH TEMP (+125 C) TEST OF ALL ICs AT RECEIVING INSPECTION

CURRENTLY IMPLEMENTING A HIGH & LOW TEMP COMBINED TEST FOR ICs

CURRENTLY EXPERIMENTALLY EVALUATING CARD TEMP CYCLING & S/P TEMP CYCLING

EQUIPMENT

SELECTED COMPLEX ITEMS SCREENED WITH TEMP CYCLING (SOME ALSO VIBRATED) AT VENDOR AND HUGHES

SYSTEM

HIGH TEMP BURN-IN AT 50° C OF ALL SYSTEMS FOR 100 HRS, LAST 24 HRS FAILURE FREE

CURRENTLY SCREENING ALL SYSTEMS AT LOW TEMP, -46° C

56/2-22

VENDOR ITEMS CONDITIONING

Vendor items conditioning included: temperature cycle units at vendor, performance test at temperature extremes and required specified failure-free time at end of cycle.

Two systems were devoted to reliability growth. They were dedicated systems to find and fix. Radars were operated in tactical situations and were used to discover problems and to proof corrective action.

Failure analysis was performed on both pattern failures and environmentally induced failures.

ESS OF PARTS/EQUIPMENT

VENDOR CONDITIONING

MAGNETIC TAPE ELECTRONIC ASSEMBLY	10 RAPID TEMP CYCLES -45 TO +71°C POWER ON
LINE PRINTER	10 SIX HOUR CYCLES -45 TO +71°C WITH POWER ON
SERVO MOTOR	RUN MOTOR/TACH 72 HRS AT RATED SPEED, ALTERNATING DIRECTION EVERY 24 HOURS TEST AFTER RUN IN
REFERENCE POWER SUPPLY	12 HOUR TEMP CYCLES, THEN TEST AT AMBIENT
AZ ENCODER	10 RAPID TEMP CYCLES, THEN TEST AT AMBIENT. VIBRATE 15 MINUTES AT 1G PEAK, THEN TEST AGAIN
HV CAPACITOR	OPERATE WITH FULL DC VOLTAGE, 12 HOURS IN 71°C OILBATH. VERIFY PROPER PERFORMANCE
TWT	45 HOUR TEST WITH VARYING CONDITIONS, MONITORING ALL TUBE FAULTS. OUTPUT POWER MUST MEET ALL REQUIREMENTS
LOW VOLTAGE TRANSCHEM POWER SUPPLIES	SPECIFIED TEMPERATURE TIME CYCLE BETWEEN -45 AND +60°C FOR ELAPSED TIME OF 45 HOURS; THEN TEST

56/2-21

FAILURE ANALYSIS/CORRECTIVE ACTION

FAILURE REPORTING ANALYSIS AND CORRECTIVE ACTION SYSTEM (FRACAS)

The Failure Review Board (FRB) is focal point for reviewing status of all failed items reported on Operation and Maintenance Reports (OMRs), field failure reports and other reported problems through the Responsible Engineering Activity (REA).

OMRs are written by systems test personnel for all operational and/or maintenance discrepancies occurring. Failed hardware is dispositioned by REA.

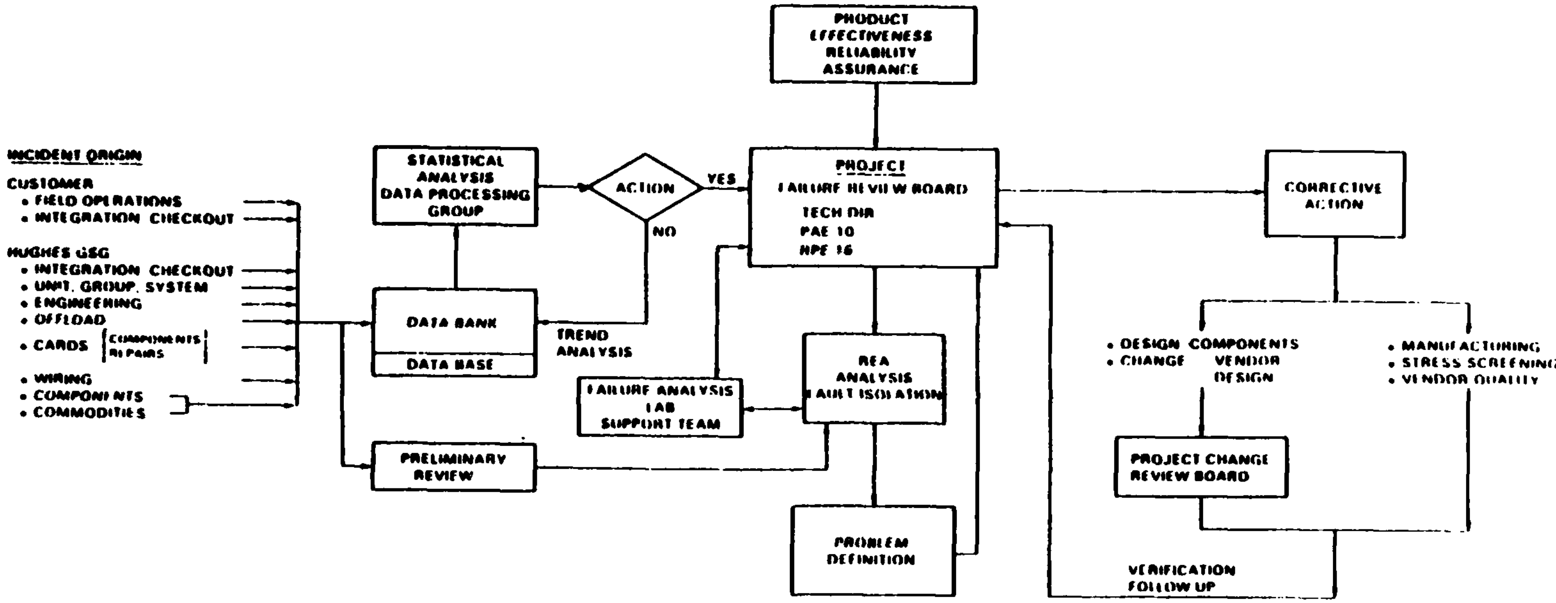
Preliminary Review Team (PRT) reviews all OMRs, field failure reports or other failure data, assigns to appropriate REA for resolution.

Factory failure trend data are compiled by Quality and Project Office FRB review. FRB assigns problems to REA.

FRB monitors progress in regularly scheduled weekly meeting of REA activity, reviews corrective actions per flow diagrams and closes items as warranted.

Test discipline assures that information required for good analyzing is preserved. Test discipline is addressed in test procedures; in strict implementation of those procedures, and in independent review of failure reports to assure completeness.

PRODUCT RELIABILITY ASSURANCE DATA SYSTEM



DESIGN LIMIT QUALIFICATION TESTING

AN/TPQ-36 ENVIRONMENTAL TEST

The AN/TPQ-36 environmental testing included qualification testing of the system in extreme environments during engineering development. As a result of the significant design changes made between the engineering development and PDR programs, risk of achieving conformance with requirements in PDR was considered high. The Risk Abatement Program was implemented to reduce this risk. The Risk Abatement program was a find and fix effort, for selected high risk environments, performed on a single early built pre-production system. The Risk Abatement Program provided early implementation of corrections in the production line, reducing the need for retrofit.

Verification of corrections and qualification of the AN/TPQ-36 design is provided by the first article test program. First article testing is performed on the first ten production systems and includes complete testing of all specified requirements.

Performance in extreme environments is also tested periodically throughout production as a part of Group C Acceptance Testing.

AN/TPQ-36 DEMONSTRATION TEST RESULTS - FIRST ARTICLE

RELIABILITY

- 2985 OPERATING HOURS AMONG 3 RADARS
- 24 RELEVANT FAILURES
- PERIODIC TRAVEL OVER ROUGH ROAD (MUNSON ROAD)
- RADAR OPERATED AT 49°C
- TEST STARTED, ABORTED BECAUSE OF EXCESSIVE FAILURES THEN RE-STARTED, COMPLETED, PASSED

ADDITIONAL AN/TPQ-36 TESTS CONDUCTED

WATER FORDING	PASSED, WITH REWORK
LOW TEMPERATURE	FAILED, IMPLEMENTED LOW TEMP SCREEN
HIGH TEMPERATURE	PASSED, WITH CORRECTIVE ACTION
5000 LAP MUNSON ROAD	PASSED
SINUSOIDAL	PASSED, WITH CORRECTIVE ACTION
ALTITUDE	PASSED, WITH CORRECTIVE ACTION
HUMIDITY	FAILED
DUST	PASSED
FUNGUS	PASSED
EMI	PASSED
NOISE LEVEL	PASSED
SYSTEM SAFETY	PASSED

AN/TPQ-36 TEST RESULTS - FIRST ARTICLE (CONTINUED)

MAINTAINABILITY

MAINTENANCE TYPE	ACHIEVED (MINUTES)	SPECIFICATION (MINUTES)
ORG MTTR	14.5	30
ORG M MAX C	28.3	120
MTTR, COMPUTER	7.2	--
M MAX/C COMPUTER	8.9	--
DS MTTR	75.5	120
DS M MAX C	145.4	240

56/2-26

AN/TPQ-37 RELIABILITY TEST

	LRIP(1)	XLRIP(2)
NUMBER OF RADARS IN TEST	2	2
TOTAL ACCUMULATED TIME IN TEST	1500 HOURS	1440 HOURS
TOTAL RELEVANT FAILURES	13	11
MTBF MEASURED	120 HOURS	131 HOURS
SPEC REQUIREMENT	90 HOURS	90 HOURS
TEST TEMPERATURE	90°F	80°F
TIME ON MUNSON COURSE	220 HOURS	400 HOURS

(1) LOW RATE INITIAL PRODUCTION

(2) EXTENDED LOW RATE INITIAL PRODUCTION

AN/TPQ-37 MAINTAINABILITY TEST

	ACHIEVED (MINUTES)	SPEC (MINUTES)
ORG MTTR (41 PROBLEMS)	27.5	30
DS MTTR	52	120
MTTR (52 PROBLEMS)	25	---
M MAX CORRECTIVE	52	---

RELIABILITY GROWTH TESTING

AN/TPQ-36 RELIABILITY GROWTH PROGRAM

PRODUCTION PHASE

The objectives of the reliability growth program were to use the TAAF (Test Analyze And Fix) principles to both surface and correct deficiencies in design, parts or workmanship. The radars are operated in a simulated field environment involving:

- Cycle system on and off
- Munson road travel
- March order and emplacement

The first 2 systems CSN #1 and #17 have completed tests accumulating over 2800 operating hours--not including non-operating time on the munson road which amounts to 200 hours. CSN #33 was started as the 3rd reliability growth radar but was diverted to a "find & fix" program at low and high temperature ($\pm$50°C)

RELIABILITY GROWTH -- AN/TPQ-36

OBJECTIVES

- TEST, ANALYZE AND FIX (TAAF)
- OPERATE RADARS IN CLOSE TO FIELD TYPE ENVIRONMENT. CYCLE SYSTEM ON AND OFF, MUNSON ROAD TRAVEL, WITH MARCH ORDER AND EMPLACEMENT

RESULTS

- CSN-1, -17 OPERATED IN ABOVE ENVIRONMENT EACH FOR APPROXIMATELY 6 MONTHS EACH, ACCUMULATING OVER 2800 OPERATING HOURS
- PROBLEMS IDENTIFIED ON OTHER RADARS WERE VERIFIED IN GROWTH RADARS
- ALL POTENTIAL FIXES WERE PROOFED AND VERIFIED WITH EXTENSIVE TEST TIME
- CSN-33 REL GROWTH RADAR WAS INITIALLY SCHEDULED FOR GROWTH PROFILE DEFINED ABOVE, BUT WAS REASSIGNED TO A FIND AND FIX RADAR AT BOTH LOW TEMP (-50°C) AND HIGH TEMP (+50°C)
- FUTURE RADARS ARE BETTER BECAUSE OF FIXES MADE IN CSNs 1 AND 17

56/2-24

AN/TPQ-36 RELIABILITY GROWTH PROGRAM

PROBLEM SUMMARY

The AN/TPQ-36 Reliability Growth Program surfaced a number of problems as shown on the chart. The Failure Review Board (FRB) was the key management tool used to focus effect on solutions. The speed and thoroughness of corrective action was critical to avoidance of production problems. This was and is being accomplished by correcting those problems where assignable causes are determined. Where they cannot be determined a historical record is kept for trend analysis.

AN/TPQ-36 RELIABILITY GROWTH PROBLEM SUMMARY

	CSN #1	CSN #17
DESIGN	TWT (2) AZ DRIVE MOTOR MEMORY CARD WEAPON LOCATOR UNIT INACCURATE	RESISTOR HI VOLTAGE RESISTOR MEMORY CARD DETECTOR DIODE SELECT RESISTOR
WORKMANSHIP	CABLE WIRE PULLOUT RF CONNECTOR LOOSE CONNECTOR PIN LOOSE POWER SUPPLY ADJ	LOOSE CRIMP RF CONNECTOR PIN PUSHED WIRE WRAP SHORT PARALENE IN PINS POWER SUPPLY ADJ
PARTS	IC CONNECTOR PIN HYDRAULIC ANTENNA DRIVE	IC - MEMORY CONNECTOR PIN HYBRID MICROCIRCUIT
NO FAULT FOUND	TAPE DRIVE STOP	MAG TAPE WON'T LOAD
OTHER		TECH MANUAL PROCEDURE MISLEADING

56/2-32

TPQ-36 RISK ABATEMENT TEST

The TPQ-36 production contract was a firm fixed price (FFP) contract with a requirement for lot acceptance based on passing periodic reliability demonstration tests. Because of known or expected reliability problems, the contractor and the U.S. Army provided a risk abatement effort where by the contractor would run those tests (along with find and fix) which the contractor determined would reduce or eliminate the risks of failing the R demo tests.

The trailer had the primary emphasis with shelters borrowed from the EDM or TPQ-37 equipment for operating the system and not necessarily included in the environment (such as high or low temperature).

The next chart shows those problems found and fixed.

AN/TPQ-36 RISK ABATEMENT TEST

- TEST (START: - DEC 1979) (END: - NOV 1980)
- FIRST PRODUCTION TRAILER (SHELTER FROM EDM/TPQ-37)
- FULL ENGINEERING CHECK PRIOR TO ENVIRONMENTAL TESTS
  - INCLUDING WEIGHT AND LATERAL STABILITY
- TESTS
  - HIGH TEMPERATURE OPERATION
  - LOW TEMPERATURE OPERATION
  - HUMIDITY
  - VIBRATION AND BOUNCE - FULLERTON MUNSON COURSE
    - A) FULL MUNSON PER EQUIPMENT SPEC.
    - B) 5000 LAPS - BELGIUM BLOCK AND POTHOLE
  - EMI
  - RAIL HUMP - SANTA FE RAILROAD
  - DUST - YUMA PG., AZ (5 HOURS)
  - WATER FORDING
  - WATER LEAK TEST
- FIND AND FIX PROGRAM

AN/TPQ-36 RISK ABATEMENT TEST

Some problems seen during TPQ-36 testing were already known while others were surfaced. The chart shows the number of problems and solutions. All potential fixes were proofed and verified with extensive test time.

Failure data tracking has shown better reliability performance on more recent equipment as a result of this early TAAF (Test Analyze And Fix) program.

One hundred and thirteen (113) problems were identified of which approximately 60 required design engineering or manufacturing engineering changes.

Failures were spread among all the major units of the system and occurred throughout various tests.

Many subtle problems were caught and corrected, such as electrical returns and shields in cables which caused transients and cross-talk.

AN/TPQ-36 RISK ABATEMENT

PROBLEM SUMMARY

PROBLEMS IDENTIFIED

DESIGN	30
WORKMANSHIP	30
PARTS	18
INDUCED	11
SECONDARY	8
NO FAULT FOUND	16
TOTAL	113

CORRECTIVE ACTIONS WERE TAKEN

57/1-31

OPERATIONAL TEST AND EVALUATION

From the initial fielding of the AN/TPQ-36 at Fort Lewis, Washington, to March, 1983, 350 operating hours have been accumulated on three systems. Five failures occurred during this period, demonstrating MTBF of 70 hours.

The maintainability achieved during this period is excellent. All five of the failures could be corrected in the field using normal organizational and direct support maintenance procedures.

AN/TPQ-36

EDM RELIABILITY (MEASURED)

TEST	HOURS	MTBF
HWLS*	1057	106
HAC RAT**	232	116
DT II	348	174
OT II	427	53
COMBINED	2064	94

*HOSTILE WEAPON LOCATING SYSTEM

**HUGHES AIRCRAFT COMPANY, RELIABILITY ACCEPTANCE TEST

AN/TPQ-37 OPERATIONAL TEST

The results of DT/OT I and III Reliability Testing conducted on low-rate initial production AN/TPQ-37 radars are shown in the figure. The data shows that the AN/TPQ-37 radars exceeded the system mission reliability and the MTBF was very close to that specified in the materiel need document. Note that there was no reliability requirement for DT/OT I, while the DT/OT III had a requirement of 90 hours.

AN/TPQ-37 OPERATIONAL TEST

ADVANCED DEVELOPMENT RADAR RELIABILITY RESULTS

DT 1	24 HOUR MTBF
OT 1	45 HOUR MTBF

(INSTANTANEOUS MTBF 63 HOURS)

LRIP RADARS RELIABILITY RESULTS

DT III	87 HOURS MTBF	1129 OPERATING HOURS
OT III	94 HOURS MTBF	566 OPERATING HOURS

AN/TPQ-37 SUCCESS OF R&M EFFORTS

The reliability of the ADM was less than that for DT/OT. A comprehensive reliability improvement program was implemented during the LRIP program and a requirement of 90 hours MTBF was established. The result of the RAM efforts applied to the AN/TPQ-37 program is illustrated by the results of DT/OT III reliability testing which demonstrated the reliability requirement was met under field conditions.

TPQ-37 OPERATIONAL TEST

ADVANCED DEVELOPMENT RADAR RELIABILITY RESULTS

DTI	24 HOUR MTBF
OTI	45 HOUR MTBF

LRIP* RADAR RELIABILITY RESULTS

DT III	87 HOUR MTBF	1129 OP HOURS
OT III	94 HOUR MTBF	566 OP HOURS

*RELIABILITY IMPROVEMENT PROGRAM WAS CONDUCTED BEFORE THE RELIABILITY DEMONSTRATION

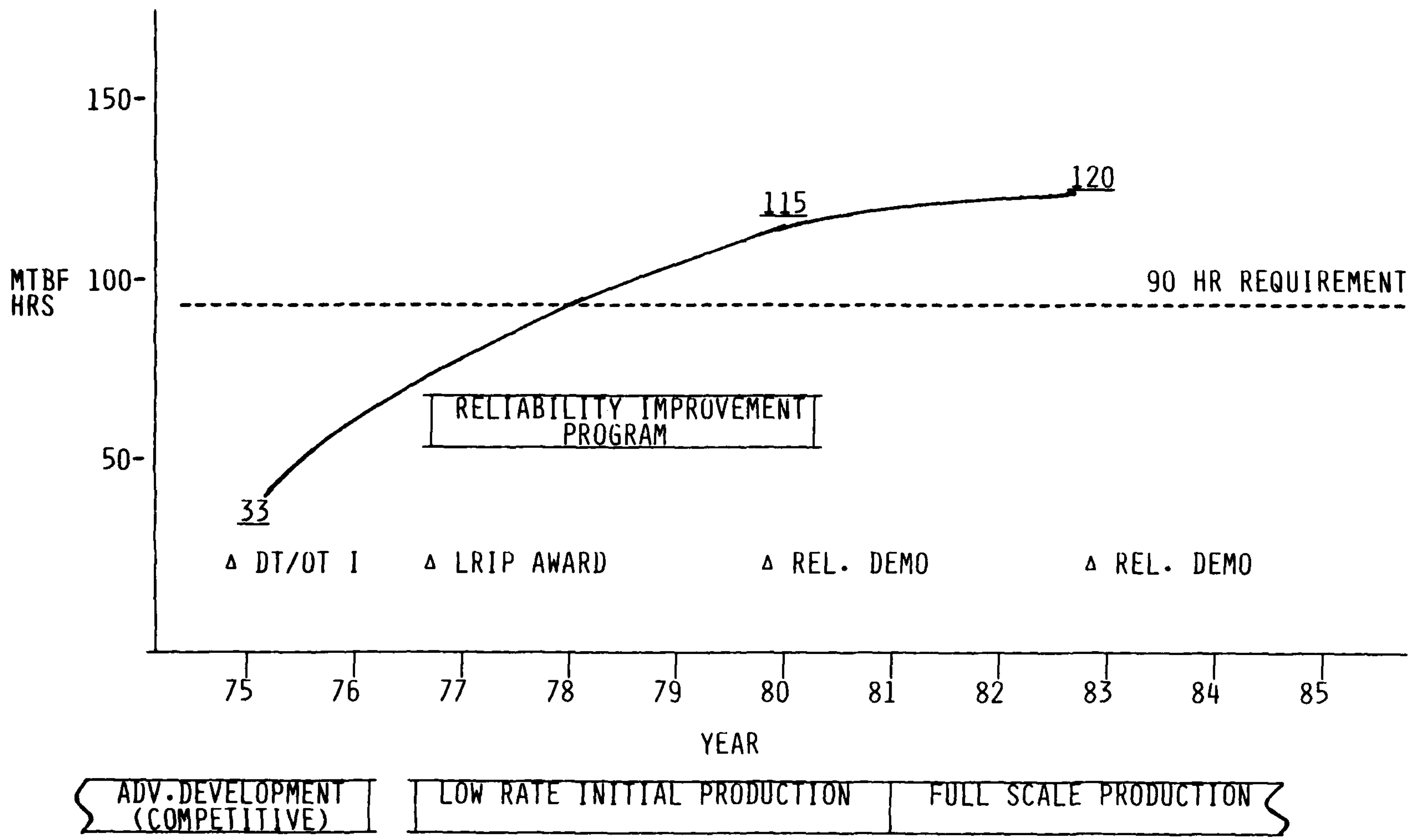
57/1-30

AN/TPQ-37 RADAR

RELIABILITY IMPROVEMENT PROGRAM BENEFITS

AD CONTRACT (1 SYSTEM)	14.6M
FSD CONTRACT	NONE
INIT. PROD. CONT. (32 SYSTEMS)	159.7M
RELIABILITY IMPROVEMENT PROGRAM (ECP)	5.5M
% OF INITIAL PRODUCTION CONTRACT	3.4%
RELIABILITY IMPROVEMENT BENEFIT	
ROI $81M ÷ 5.5M	15:1
READINESS	
SYSTEM RELIABILITY IMPROVEMENT	~ 3:1

93/19-2



TPQ-37 RELIABILITY GROWTH

FIELD DATA COLLECTION

FIELD DATA COLLECTION

Firefinder field data collection will identify problems in RAM areas for improvement during the deployment phase of the system life cycle. The program was initiated in the February-March 1983 time frame with visits to Fort Lewis, Washington, and Fort Hood, Texas. As a result of these visits, preliminary field MTBFs have been obtained and changes required in operational and maintenance procedures and technical manuals identified.

FIREFINDER FIELD DATA COLLECTION

PURPOSE

- ASSESS RAM IN THE FIELD
- IDENTIFY PROBLEMS THAT OCCUR IN FIELD FOR RESOLUTION

SCOPE

- MEASURE FIELD RAM AT FOUR SELECTED USE UNITS IN VARIOUS LOCATIONS AROUND THE WORLD
- TRACK RAM AT EACH USER UNIT FOR ONE-YEAR PERIOD AFTER INITIAL FIELDING

RESULTS

- TPQ-36 AT FORT LEWIS, WASHINGTON
  - MTBF ~ 70 HOURS
  - MAINTAINABILITY - GOOD
  - SYSTEM PROBLEMS IDENTIFIED FOR RESOLUTION
  - TM PROBLEMS IDENTIFIED FOR RESOLUTION
- TPQ-37 AT FORT HOOD
  - MTBF ~ 50 HOURS
  - MAINTENANCE PROBLEMS IDENTIFIED FOR RESOLUTION
  - SYSTEM PROBLEMS IDENTIFIED FOR RESOLUTION
  - TM PROBLEMS IDENTIFIED FOR RESOLUTION

57/1-35

TEST COSTS

AN/TPQ-36 TEST COSTS

	COST @ SELL
EDM DEVELOPMENTAL TESTING (5 RADARS)	
SYSTEM INTEGRATION AND TEST (1972-1976)	1,500,000
ENVIRONMENTAL TESTING (1976)	400,000
EDM OPERATIONAL TESTING	
LIVE FIRE TEST (1975-1976)	800,000
SUPPORT FT. CARSON (1977)	300,000
EUROPEAN DEPLOYMENT (1978-1981)	2,100,000
FULL SCALE PRODUCTION (154 RADARS)(1978-1985)	
FIRST ARTICLE TEST	700,000
RISK ABATEMENT TESTING	800,000
MAINTAINABILITY DEMO	300,000
RELIABILITY DEMO	2,300,000
QUALITY CONFORMANCE TESTING	1,600,000
SYSTEM INTEGRATION AND TEST	2,800,000
LIVE FIRE TEST	3,400,000
TOTAL ALL TESTING	$17,000,000

AN/TPQ-37 TEST COSTS

	COST @ SELL
AN/TPQ-37 LRIP (1976-1980) 10 RADARS	
SYSTEM INTEGRATION & TEST	$ 2,800.000
ENVIRONMENTAL TEST	200,000
RELIABILITY DEMO	500,000
LIVE FIRE TEST	400,000
AN/TPQ-37 XLRIP (1979-1983) 22 RADARS	
SYSTEM INTEGRATION & TEST	900,000
ENVIRONMENTAL TEST	600,000
RELIABILITY DEMO	700,000
LIVE FIRE TEST	700,000
AN/TPQ-37 FULL-SCALE PRODUCTION (1982-1985) 40 RADARS	
SYSTEM INTEGRATION & TEST	4,300,000
ENVIRONMENTAL TEST	4,200,000
RELIABILITY DEMO	1,900,000
LIVE FIRE TEST	2,900,000
TOTAL ALL TESTING	$20,100,000

100/29-1

CONTRACT COSTS

AN/TPQ-36 MOBILE WEAPONS LOCATING RADAR CONTRACTS

DATE	CONTRACT	DESCRIPTION	SCOPE	VALUE
10/73	DAAB07-74-C-0012	DESIGN & MANUFACTURE FIVE ENGINEERING DEVELOPMENT MODELS (EDM)	5 EDMs	35,600,000
04/78	DAAB07-78-C-2409	AN/TPQ-36 RADAR SYSTEM PRODUCTION	154 SYSTEMS	219,400,000
	MOD PZ0039	NETHERLANDS FMS	7 SYSTEMS	14,400,000
	MOD P00067	SAUDI FMS	7 SYSTEMS	18,600,000
	MOD P00093	JORDAN/THAILAND/SINGAPORE FMS	10 SYSTEMS	20,200,000
	MISC MODS	PROV. ITEMS, ETC.	----	10,900,000
05/80	DAAK20-80-C-0027	ENGINEERING SUPPORT FOR EUROPEAN DEPLOYMENT OF 2 EDMs		600,000
06/81	DAAK20-81-C-0380	TRANSMITTER TEST BED		500,000
			TOTAL	320,200,000

56/1-42

AN/TPQ-37 MOBILE WEAPONS LOCATING RADAR CONTRACTS

DATE	CONTRACT	DESCRIPTION	SCOPE	VALUE
06/72	DAAB07-72-C-0299	DESIGN & MANUFACTURE ADVANCE DEVELOPMENT MODEL	1 ADM	14,600,000
05/76	DAAB07-76-C-0893	PHASE I - MOD & REFURB. ADM PHASE II- LOW RATE INITIAL PRODUCTION	10 SYSTEMS	77,700,000
09/78	DAAB07-78-C-2460	QUALITY ASSURANCE PROGRAM	---	2,700,000
10/78	DAAB07-78-C-0310	TRANSMITTER TEST BED	---	400,000
02/79	DAAK20-79-C-0010	EXTENDED LOW-RATE INITIAL PRODUCTION	22 SYSTEMS	82,000,000
09/79	DAAK20-79-C-0029	DESIGN, FAB & INTEGRATE & TEST 2 SECONDARY EMITTERS		4,500,000
05/81	DAAK20-81-C-0134	FULL-SCALE PRODUCTION	40 SYSTEMS	209,000,000
09/81	DAAK20-81-C-0149	MODIFY & TEST ALTERNATE TRAILER	---	600,000
03/82	DAAK70-82-C-0051	SCATTERMINE DETECTION INVESTIGATION	---	1,400,000
03/82	DAAK20-83-C-0130	TRAVELING WAVE TUBE IMPROVEMENT	---	3,600,000
			TOTAL	396,500,000

56/1-42

AN/TPQ-36/37 SUPPORTING CONTRACTS

DATE	CONTRACT	DESCRIPTION	SCOPE	VALUE
08/77	DAAB07-77-C-0587	NEAR FIELD ANTENNA MEASUREMENT	---	700,000
09/79	DAAK20-79-C-0024	EQUATE PROGRAM SETS	---	3,700,000
09/80	DAAK20-80-C-0043	DEPOT TEST PROCEDURES & EQUIPMENT	---	5,900,000
07/81	DAAK20-81-C-0147	LOGISTIC SUPPORT	---	6,700,000
09/81	DAAK20-81-C-0206	ENGINEERING SERVICES & SUPPORT	---	1,500,000
			TOTAL	18,500,000

56/1-43

LESSONS LEARNED

LESSONS LEARNED

DESIGN	
• CONDUCT ADEQUATE MECHANICAL STRESS ANALYSIS UP FRONT	AVOID R/M PROBLEMS, COST OF CHANGES
• CONFIGURATION CONTROL	SHOULD FOLLOW SUCCESSFUL COMPLETION OF QUALIFICATION TESTING
• CYCLE FOR SUBMITTING/APPROVING/ ACCOMPLISHING DESIGN CHANGES IS TOO SLOW	EXCESSIVE IMPLEMENTATION COST AND RETROFIT RESULTS
QUALIFICATION	
• COMPLETE QUALIFICATION TESTS BEFORE PRODUCTION STARTS	AVOID EXPENSIVE "ONE AND UP" CHANGES AND AVOID EARLY RELIABILITY PROGRAMS
• USE 10% SYSTEM STRESS SCREENING INSTEAD OF LOT QUALITY CONFORMANCE TESTS	RADARS RECEIVE SCREENS DESIGNED TO REDUCE FIELD FAILURES AND REDUCE RISK TO SCHEDULE DUE TO UNIT LOT REJECTIONS
• HUMIDITY REQUIREMENTS DIFFICULT	DETERMINE REALISTIC REQUIREMENTS BASED ON MISSION NEED AND LIFE PROFILE
• GOOD SIMULATION OF REAL ENVIRONMENT IS IMPORTANT	

LESSONS LEARNED

BIT

• USE CONSERVATIVE M ON N CRITERIA	BASED ON SYSTEMS NEEDS AND IMPLICATIONS OF SIGNAL TRANSIENTS AND SPURIOUS SIGNALS AN M OF N DESIGN WILL AVOID NEEDLESS SHUTDOWNS AND TROUBLE-SHOOTING
• THOROUGH BIT DESIGN PAYS OFF IN REDUCED TEST/OPERATING COST	A RELATIVELY HIGH BIT COST IS JUSTIFIED BECAUSE HIGH PROBABILITY OF DETECTING/ISOLATING FAULTS AND LOW PROBABILITY OF FAULTS AND LOW PROBABILITY OF FALSE ALARM IS A FACTOR IN LOW LIFE CYCLE COST

56/1-45

LESSONS LEARNED

RELIABILITY/QUALITY CONTROL/MANUFACTURING

• FIAR (FAILED ITEM ANALYSIS REPORTS) SYSTEM DILUTES EFFORTS FROM BIG SWINGERS (FAILURE CAUSES)	ENERGY (TIME AND MONEY) NEED TO BE DEVOTED TO DEFECTS HAVING MOST SIGNIFICANT IMPACT ON RELIABILITY
• INCENTIVES HAVE A POSITIVE EFFECT ON RELIABILITY	CONTRACTORS SEEK AND RESPOND TO HIGHER PROFIT AND ENHANCED REPUTATION
• DERATING GUIDELINES NECESSARY	DERATING MUST OCCUR FOR OPTIMUM COST, RELIABILITY. THEY MUST BE DISSEMINATED EARLY TO DESIGNERS AND "BUILT IN" TO THE DESIGN EFFORT
• QUALIFICATION TEST FAILURE EXPECTATIONS MUST BE DEFINED	QUALIFICATION TESTS ARE STRESS TESTS AND SOME COMPONENT FAILURES SHOULD BE ANTICIPATED THAT DO NOT CONSTITUTE TEST FAILURE
• RELIABILITY TEST SCORING RULES MUST BE DEFINED	SCORING RULES MUST BE REALISTIC BOTH FROM GOVERNMENT AND CONTRACTOR SIDE AND CLEARLY DEFINED TO PREVENT CONTROVERSIAL SCORING CONFERENCES. EFFORT SHOULD BE DIRECTED AT CAUSE AND CORRECTIVE ACTION
• DEDICATED RELIABILITY GROWTH SYSTEMS ARE ESSENTIAL	TPQ-36 RISK ABATEMENT PROGRAM FOUND OVER 100 PROBLEMS
• FIND AND FIX SHOULD DRIVE EARLY TEST ACTIVITY RATHER THAN NUMERICAL MEASUREMENT AND SCORING	POTENTIAL PROBLEM AREAS SHOULD DIRECT THE NATURE OF TESTS AND ALL EFFORT SHOULD USE CONCEPTS OF FIND AND FIX

PURCHASED ITEMS

• IMPROVE SCREENING OF COMPONENTS	BETTER YIELD AND LESS EARLY FAILURE
• USE "MAKE FROM" DRAWINGS	UPGRADE COMPONENTS RELIABILITY IN HOUSE, WHEN VENDORS CANNOT SUPPLY REQUIRED QUALITY LEVEL

LESSONS LEARNED

PURCHASED ITEMS (Continued)	
• PASS DOWN RELIABILITY PROGRAM REQUIREMENTS TO COMPLEX ITEM SUPPLIERS	COMPLEX ITEMS SHOULD NOT BE TREATED AS "BLACK BOXES" BUT GIVEN CONSISTENT RELIABILITY TREATMENT SUCH AS DERATING, DESIGN ANALYSIS, PARTS CONTROL AND STRESS SCREENING
• FEEDBACK FAILURE DATA TO VENDORS	TREAT VENDORS AS PART OF WHOLE PRODUCTION EFFORT AND DEMAND CORRECTIVE ACTION.
PROCESSES	
• USE SOLDER MASK TO REDUCE SOLDER FAILURES	SOLDER IS BY NATURE A VARIABLE PROCESS AND SOLDER MASK REMOVES MANY VARIABLES. SOLDER DEFECTS ARE THE SECOND HIGHEST CLASS OF WORKMANSHIP DEFECTS
• PROCESS CONTROL CRITICAL	ANALYSIS AND FEEDBACK OF DOWNSTREAM FAILURES TO POINT OF ORIGINATION ALONG WITH POSITIVE CORRECTIVE ACTION IS OPTIMUM COST/RELIABILITY STRATEGY

Reliability Incentives Don't Work if They're Not Clearly Defined

Early in the AN/TPQ-36 development program, it was decided to amend the contract to add a Design to Cost (DTC) program with a supplementary award fee provision. In order to prevent the design to cost effort from having a negative impact on reliability or performance, the award fee stated that the first two increments of the award fee were payable on design to cost, reliability and performance. (The last two increments were based solely on the overall acceptability of the contractor's production proposal.) The contractor knew how much could be payable in total fee for each increment, but not what the ratios would be for DTC, reliability or performance. The criteria for determination of the reliability portion of the award was somewhat vague. As it turned out, the first and second increments were awarded as follows:

	Increment I (Max $127,500)		Increment II (Max $135,150)	
	Weight	Awarded	Weight	Awarded
DTC Management	40%	$44,242	15%	$20,273
Technical Performance	35%	43,733	15%	6,487
Reliability Growth	25%	31,875	70%	0
	100%	$119,850	100%	$26,760

In this case the award fee for reliability was not effective. The contractor believed that the DTC portion was far more important than reliability, because 1.75 million dollars was invested in the DTC program. The contractor was, therefore, surprised by the second increment.

The contract clause should have defined the exact levels that could have been payable for all elements of the award fee, which clearly defined criteria for determiniation of award. It is impossible to determine if the end product would have been significantly different, but the Government should have clearly defined what the fee was based on.

Reliability Growth is a Slow Process and Requires a Dedicated Effort with Hardware Dedicated for the Sole Purpose of Find/Fix

During development programming, there is normally great demand for a limited number of development model systems. The reliability growth program must compete with other programs such as: software debugging, performance testing, environmental testing, DT/OT training, etc. For a successful reliability growth program system assets must be dedicated to the testing required to find design weaknesses and to verify design corrections.

The find/fix program must be scheduled and budgeted as a normal phase of a development program, and it must be scheduled early enough to allow changes to be incorporated into the system and verified during tests. The contractor must have a system available to investigate problems and to verify the effectiveness of any fixes.

Reliability Growth at the Subsystem can Pay Off

Reliability growth or find/fix programs have, in the past, been system oriented. This can be cumbersome for large complex systems, where as many as twelve different engineers are investigating problems in different subsystems of a single system. It is generally obvious that certain subsystems will be the pacing elements in the reliability chain, and it would be desirable to concentrate the reliability effort on the potentially problem subsystems.

The find/fix program for the AN/TPQ-37 Artillery Locating Radar was performed at both the system and subsystem levels during LRIP. The transmitter and receiver/exciter subsystems have been the pacing elements in the reliability chain, and a separate find and fix program is part of the contract. Transmitter S/N 10 was built in parallel with S/N 1 so that it could undergo a find/fix program. It was then refurbished and installed in system S/N 10. A prototype receiver/exciter was built and subjected to extensive thermal testing.

The Importance of Reliability Must Be Emphasized in a Development Contract

The Army should emphasize the importance of reliability in the contract. The contractor knew that all of the requirements may not be met and, in fact, that the Government would be satisfied if the major requirements were met and the system was reasonably close to meeting the other requirements. As does every development contract, this contract contained numerous pages of requirements, i.e., accuracy, weight, delivery schedule, environmental requirements, EMI, cost, etc. There was no ranking of priorities in the contract, and obviously, each of the many requirements did have a different priority. Contractors also tend to prioritize requirements based on the amount of money made available for the requirement.

Performance parameters, including reliability, should be prioritized in the development contract.

Maintaining a Technical Repesentative at Independent Government Test Sites Is Essential

A technical liaison must be maintained with a system being tested by any independent test organization. (This, of course, also applies during contractor tests.) Early in the DT II test program, inaccurate EPRs were issued by the test agency. These discrepancies mixed failures during high temp, low temp, and humidity, and could have led the independent evaluator and the developer to draw the conclusion that the wrong test was failing. These discrepancies were corrected immediately, when the FIREFINDER liaison brought them to the attention of USATECOM.

Major problems can become miniscule when knowledgeable technical support is available to the tester. This can often prevent "cockpit" or technical manual problems from surfacing as major equipment problems or deficiencies.

The Maintainability Demonstrations (MIL-STD-471) Normally Run During Development are of Questionable Value

The "Normal" maintainability program requires the contractor to submit a Maintainability Demonstration Plan which includes a list of candidate faults that can be selected for the demo. The list is statistically valid as required by the MIL-STD-471 but, as is often the case, the faults were tried in the system before they were submitted to the Government as part of the fault pool. If some of the faults could not be detected, they were easily replaced with other faults. MIL-STD-471 also does not require the contractor to use the TM which he wrote for Army personnel. During discussions with several local engineers who have witnessed maintainability demos, not one was able to recall any contractor at any time failing a maintainability demo. The demo must be performed with a fault pool selected by the Government, or at least jointly by the contractor and Government. The intent of the demo is to verify the maintainability of the system, including hardware, software and technical manuals. TMs must be used during the demo and the demo should be failed if the TMs do not lead the mechanic to the fault and provide adequate direction for the repair.

Failure Analysis to Identify and Correct Manufacturing Defects

During development, the failure analysis program was effective in identification of design errors and in providing design correction. In development, manufacturing defects were considered unimportant and little attempt was made to resolve them. By the time that the system is in production, most of the design errors have been eliminated and most system failures are caused by manufacturing defects. To maintain acceptable levels of reliability in production, the manufacturing defects which cause system failures must be traced back to the source and the manufacturing process control must be improved. The failure analysis program which was developed to address design problems was not effective in addressing manufacturing problems. To effectively address manufacturing defects, the engineer performing the analysis must recognize this change of emphasis and the failure analysis team must include factory quality and production personnel. It is difficult to obtain a permanent correction for manufacturing defects. The failure analysis program must be able to effect changes to work instructions, drawings, inspection, and tools in order to reduce the frequency of defects.